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CHEMISTRY

OF THE

FOUR ANCIENT ELEMENTS

RE, AIR, EARTH, AND ATER,

AN ESSAY,

FOUNDED UPON

URES DELIVERED BEFORE HER MOST GRACIOUS MAJESTY

THE QUEEN,

DEDICATED BY SPECIAL PERMISSION TO HER MAJESTY.

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LONDON:

SAMUEL HIGHLEY, 32, FLEET STREET.

1842.

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TO

ER MOST GRACIOUS MAJESTY

THE QUEEN,

BY SPECIAL PERMISSION,

This Essay

ON

THE CHEMISTRY

OF

'IE FOUR ANCIENT ELEMENTS,

FOUNDED UPON LECTURES DELIVERED BEFORE

HER MAJESTY,

IS DEDICATED

WITH SENTIMENTS OF PROFOUND GRATITUDE

AND FERVENT LOYALTY,

BY

R MAJESTY'S MOST HUMBLE AND DEVOTED SERVANT,

THOMAS GRIFFITHS.

ADVERTISEMENT.

This Essay on the Chemistry of the Four Ancient Elements is chiefly intended for those who have not studied the Science.

Abstruse details and theories are therefore avoided, useful and interesting information supplied, and instruction united with entertainment.

Explicit directions are given respecting the performance of the Experiments, and cautions concerning the nature of several agents employed during the inquiry, will be found in the Appendix.

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INTRODUCTORY.

A DARK and mysterious art, called Alchemy, which originated with the Arabian sages about the seventh century, was the parent of the brilliant and enchanting science of Chemistry. Philosophers of the polemical schools maintained that Fire, Air, Earth, and Water, were the Four Elements of Nature; but the disciples of alchemy denied the validity of this doctrine, and asserted that Salt, Sulphur, and Mercury, were the Three Elements, from whose admixture or union emanated the various productions of the animal, vegetable, and mineral kingdoms.

Both notions were erroneous, as the sequel will prove, but that of the alchemists rapidly,

excited intense interest, because it led to the performance of curious experiments, and to the observance of strange phenomena attendant upon the mixture of acids, salts, spirits, and metals. Thus, under the hands of the alchemists, pellucid liquids changed into opaque solids, brilliant metals vanished into coloured solutions and suddenly re-appeared in their original forms. These, and other unexpected and apparently magical results, were well calculated to arrest the curiosity and astonishment of the operators, who, finding themselves gifted with the power of eliciting such marvels, rashly imagined that they could actually create substances, or transmute them into each other. Avarice immediately prompted the most ardent exertions to be made to change worthless lead into precious gold, and held forth the luring hope, that the mere alteration of the quantity of Salt, Sulphur, and Mercury of the one metal would cause its Transmutation into the other.

The alchemists therefore, constructed powerful furnaces, invented curious stills, alembics, retorts, crucibles, and much costly and complicated apparatus for extracting strong acids,

salts, and solvents, from minerals and earths. Aided by these they commenced an arduous search throughout all Nature, for an imaginary substance, which they named the Philosopher's stone. A minute fragment of this miracle of art, when discovered, and thrown upon molten lead, was destined to alter the proportions of its three supposed elements, to cleanse it from impurity and dross, and transmute it into pure and effulgent gold.

From the laboratories of Arabia, the principles of this seductive art soon spread over Europe, and all ranks of society joined in wild pursuit of the golden phantom for a long succession of ages. Vain was their incessant toil and labour, it eluded their anxious grasp, and instead of enjoying riches and splendour, they invariably languished in poverty and misery.

The alchemists, baffled in the acquisition of metallic treasure, sought after a powerful liquid for dissolving all things; but this was quickly abandoned, because an Universal solvent could not be contained in their retorts or crucibles. Ultimately they dared to think Immortality within their reach, and pre-

sumptuously endeavoured to prepare a medicine to prevent the decay of nature, and prolong life to an indefinite extent; but disease and death were the grim attendants upon the operators, who trusted to obtain an Elixir of life amidst the poisonous fumes of the furnace.

Such were the three grand objects of alchemic art, and though abortive in regard to their anticipated results, yet productive of the good effect of inducing philosophers to descend from disputes upon words, to experiments upon things. Accordingly, out of the vast mass of intricate materials accumulated by the alchemists, a few master minds were enabled to select, examine, and classify valuable facts, striking experiments, and wonderful phenomena, which had been either abandoned or forgotten during the infatuated pursuits now briefly described.

The gradual introduction of metallic preparations into Medicine, as substitutes for the drugs and simples of its ancient practice, and of others into the arts and manufactures, conjoined with the publication of essays concerning these and other experimental facts, eventually drew the attention of civilized

society to the utility of the labours of the philosophers, who engaged upon the ruins of the once dearly cherished, yet delusive art, and in an incredibly short time, like the fabled Phœnix of Arabia, Chemistry soared from the ashes of Alchemy.

Chemistry, guided by accurate experiment and sound theory, has attained its just rank in the circle of the sciences, and has proved the intimate connexion of its beautiful facts and doctrines, with the wonderful phenomena of the world, and their great utility when judiciously applied to the arts of life, in aid of the wants, comforts, and luxuries of mankind.

The votary of Chemistry, is not chained to the flaming furnace in fruitless labour after gold, nor compelled to invoke witchcraft and magic for the production of an universal solvent, nor immured in the dark laboratory, amidst deadly exhalations, to discover the art of prolonging life; in this happy age, the fetters of ignorance and superstition, are shattered by the powerful hand of Truth, and he comes forth with freedom into the glowing sunlight of Philosophy, as the servant and interpreter of Nature; he looks abroad into the

rich and magnificent Universe, calls the delightful scenery all his own, the mountains, the valleys, the oceans, the rivers, and the sky; through these wide bounds he is free at will to choose

> "Whate'er bright spoils the florid earth contains,
> Whate'er the waters, or the ambient air,"

All present him with perfect instances of the consummate wisdom of the Almighty God, who created a World so fraught with beauty, and by their examination he gains materials for reflection and research, which, if properly applied and pursued, not only enlighten and adorn, but exalt and purify his mind, teaching him to appreciate the miraculous workings of an Omnipotent and Eternal Power.

Chemistry is the most instructive and delightful study that can be pursued, because it is purely a science of Experiment; no anticipations can be formed as to the results which will ensue upon the presentation of different substances to each other. By making experiments with great attention and accuracy, and intently studying the results, philosophers

soon discovered the real nature of the Four ancient, and the Three alchemical Elements; a short account of the conclusions which are thus established will furnish a correct notion of the modern meaning of the term Elements, which will frequently occur during the present inquiry.

Fire, is not a peculiar or distinct principle, but a result of intense attraction between two or more substances. Air, is a mixture of two gases, called Oxygen and Nitrogen. Earth, is a compound of Oxygen and numerous Metals. Water, is a compound of Oxygen and a gas called Hydrogen.

Salt, is a compound of a vapour called Chlorine, and a metal called Sodium; but the components of Sulphur and Mercury are unknown, therefore these two substances are called Elements, to denote that they have not been analysed, and in this acceptation of the term Oxygen, Nitrogen, Hydrogen, Metals, and several other substances, are Elements; altogether there are Fifty-five such Elements: their names are shown in the following list.

MODERN ELEMENTS,

AND DERIVATION OF THEIR NAMES.

ALUMINUM. A metal thus named from the Latin *alumen, clay.*

ANTIMONY. A metal thus named from the Greek ἀντι, *against,* and μονος, *monk,* because several monks were poisoned by its preparations.

ARSENIC. A metal thus named from the Greek ἀρσενικον, *powerful,* on account of its strength as a poison.

BARIUM. A metal extracted from Baryta, a heavy mineral thus named from the Greek, βαρυς, *weight.*

BISMUTH. A metal said to be thus named by the German miners, from *wiessmatte, a blooming meadow,* because of the variegated hues of its tarnish.

BORON. A non-metallic combustible, obtained from Borax, a substance so called from the Arabic, *burruk, brilliant.*

BROMINE. A non-metallic incombustible liquid; its name is derived from the Greek, βρωμος,

stench, on account of the insupportable odour of its vapour.

CADMIUM. A metal thus named from the Greek καδμεια, *calamine*, an ore of zinc.

CALCIUM. A metal thus named from the Latin *calx*, *lime*.

CARBON. A non-metallic combustible, thus named from the Latin *carbo*, *coal*.

CERIUM. A metal thus named in honour of the planet *Ceres*.

CHLORINE. A non-metallic incombustible vapour, thus called from the Greek χλωρος, *green*, in allusion to its colour.

CHROMIUM. A metal thus named from the Greek χρωμα, *colour*, on account of the varied hues which its compounds assume.

COBALT. A metal thus named after *Kobold*, a sprite or gnome of the German mines.

COLUMBIUM. A metal thus named from its discovery in a mineral from *Columbia*.

COPPER. A metal thus named from being originally wrought in *Cyprus*.

FLUORINE. A non-metallic uninflammable vapour, extracted from *fluor-spar*.

GLUCINUM. A metal extracted from a mineral named Glucina; a term derived from the

Greek γλυκυς, *sweet*, on account of such taste being communicated by its compounds.

GOLD. A metal the etymology of whose name is uncertain.

HYDROGEN. A non-metallic inflammable gas, and being an element of water, it is thus called from the Greek ὑδωρ, *water*, and γενω, *to generate.*

IODINE. A non-metallic incombustible solid, which emits a violet-coloured vapour by heat, the name by which it is distinguished is derived from the Greek ιωδης, *violet coloured.*

IRIDIUM. A metal thus named in honour of *Iris*, on account of the rainbow hues which some of its compounds assume.

IRON. A metal the etymology of whose name is obscure.

LANTANUM. A metal, which from its long concealment amidst others, was thus called from the Greek word λανθανειν, *to lurk.*

LEAD. A metal thus named from the Greek μολυβδος.

LITHIUM. A metal extracted from a mineral named Lithia, from the Greek λιθειος, *lapideus.*

MAGNESIUM. A metal obtained from *Magnesia*, so called from being found in a province of that name in Asia Minor.

MANGANESIUM. A metal, the origin of whose name is undetermined.

MERCURY. A fluid metal, thus named in honour of the heathen deity *Mercury*.

MOLYBDENUM. A metal thus named from the Greek word μολυβδος, *lead*.

NICKEL. A metal thus named from the German *kupfernickel*, *false copper*.

NITROGEN. A non-metallic gas, incombustible, and a non-supporter of combustion, thus named from the Greek νιτρον, *nitre*, and γενω, *to generate*, as under certain conditions it produces nitre.

OSMIUM. A metal thus named from the Greek οσμη, *odour*, on account of the peculiar odour of some of its compounds.

OXYGEN. A non-metallic uninflammable gas, but a supporter of combustion, and producer of acids; hence its name from the Greek οξυς, *acid*, and γενω, *to generate*.

PALLADIUM. A metal thus named in honour of the planet *Pallas*.

PHOSPHORUS. A non-metallic solid inflammable

substance thus named from the Greek φως, *light*, and φερειν, *to bear*, because it emits light in the dark.

PLATINUM. A metal thus named from being first discovered near the river *Plata*.

POTASSIUM. A metal extracted from *potash*; a substance anciently prepared by burning weeds to *ashes* in iron *pots*.

RHODIUM. A metal whose combinations assume a red colour; hence its name from the Greek ῥοδων, *a rose*.

SELENIUM. A non-metallic inflammable element thus named in honour of the moon from the Greek σεληνη, *the moon*.

SILICIUM. A metal thus named from the Latin *silex*, *flint*.

SILVER. A metal, the origin of whose name is obscure.

SODIUM. A metal obtained from the ashes of a plant called the *salsola soda*.

STRONTIUM. A metal extracted from a mineral discovered at *Strontian*.

SULPHUR. A non-metallic combustible, whose name is probably of Arabic extraction.

TELLURIUM. A metal thus named in honour of the Earth, from the Latin *Tellus*, *the earth*.

THORINUM. A metal thus named in honour of the Saxon deity *Thor*.

TIN. A metal, the origin of whose name is a matter of doubt.

TITANIUM. A metal thus named in honour of the *Titans* of heathen mythology.

TUNGSTENUM. A metal thus named from the Swedish word *tungsten, heavy-stone*, from which it was extracted

URANIUM. A metal thus named in honour of the plant *Uranus*.

VANADIUM. A metal thus named in honour of *Vanadis*, a Scandinavian deity.

YTTRIUM. A metal extracted from a mineral found at *Ytterby*.

ZINC. A metal supposed to be thus named from the German *Zinken, nails*.

ZIRCONIUM. A metal obtained from a gem called *Zircoon*, by the Cingalese, in allusion to its four-cornered shape.

By far the greater number of the above host of elements have been elicited by chemical analysis; very few are presented absolutely pure by Nature.

The Elements may be thus classed:

I. Forty-three Metals, Aluminum, Antimony, Arsenic, Barium, Bismuth, Cadmium, Calcium, Cerium, Chromium, Cobalt, Columbium, Copper, Glucinum, Gold, Iridium, Iron, Lantanum, Lead, Lithium, Magnesium, Manganesium, Mercury, Molybdenum, Nickel, Osmium, Palladium, Platinum, Potassium, Rhodium, Silicium, Silver, Sodium, Strontium, Tellurium, Thorinum, Tin, Titanium, Tungstenum, Uranium, Vanadium, Yttrium, Zinc, and Zirconium.

II. Three Gases, Hydrogen, Oxygen, and Nitrogen.

III. Two Vapours, Chlorine and Fluorine.

IV. One Non-metallic fluid, Bromine.

V. Six Non-metallic solids, Boron, Carbon, Iodine, Phosphorus, Selenium, and Sulphur.

The Supporters of combustion are, Bromine, Chlorine, Fluorine, Iodine, and Oxygen.

The Combustibles are, Boron, Carbon, Hydrogen, Phosphorus, Selenium, and Sulphur.

It must be particularly remembered that the Chemist does not affirm these substances to be the Atomic, or Absolute Elements of Nature; on the contrary, he deems it extremely proba-

ble, that they may be analysed or decomposed in the course of time, but until this be effected, he styles them Elements for convenience of discussion, and as a confession of the limits of his analytical skill.

The Chemist investigates the habitudes of these Elements, discovers how they combine to form Compounds, and how these combine to form Double compounds; he ascertains the Weight in which these Primary and Secondary combinations ensue, and how the elements of all known compounds may be Separated; he determines the Laws which preside over all these changes, and studies to apply such knowledge to the interpretation of Natural phenomena, and to Useful purposes in the Arts of life.

Throughout these extensive researches the Chemist depends entirely upon Experiment; and the marvels which it reveals, are referrible to the exertion of a Power which promotes union between Elements and Compounds, even though their natures be strongly opposed.

This power is called Chemical Attraction, Attraction of Composition, or Chemical Affinity, the latter term being used in a figurative sense, to suggest the idea of peculiar attachments

between different substances, under the influence of which they combine so that their individual characters are totally changed and disguised. Thus, the Elements Hydrogen and Oxygen, are Gases viewless as air, the one combustible, the other incombustible, and they are opposed in other respects, but they have mutual affinity, and combine to form the Liquid Compound called Water.

The Compounds called Carbonic acid, and Lime, are strangely opposed in character, the former being an invisible acid Gas, the latter a white acrid Solid, yet they have mutual affinity, and combine to form a Double compound, white, solid, and tasteless, called Carbonate of Lime, or Chalk.

These examples will be sufficient to explain the meaning of the term Chemical Affinity, and its power will be found active throughout the ensuing examination of The Chemistry of The Four Ancient Elements, Fire, Air, Earth, and Water.

CHAPTER I.

FIRE.

GREEK, πῦρ; LATIN, *ignis*: FRENCH, *feu*.

THE wonderful phenomena exhibited by Fire, the beauty of its ruddy glow or flickering flame, must have excited the attention of the earliest inhabitants of the globe; how it was first revealed to their startled sight, whether by the vivid lightning's flash, the fall of burning meteors, or the terrific flame of volcanic eruptions, is a matter which will for ever remain in mystery.

The value of fire was soon appreciated, its effects understood, its existence cherished, and artificial means devised of eliciting it at will, as an agent of comfort, utility, or destruction.

The mutual friction of two pieces of dry

wood was employed in very ancient times as a source of fire. Pliny states that bay and ivy wood were selected for the purpose; and it is a well-attested fact, that some savage tribes yet resort to similar means, though the kind of wood which they use is not exactly known. The violent collision of two lumps of an ore, now called the Bisulphuret of iron, was also an ancient method of obtaining fire, and hence the ore obtained the name of Pyrites, or Fire-stone, from the Greek word πυριτης; it is used at present by the Patagonians.

When two lumps of Pyrites are struck together, brilliant sparks appear, which are little fragments of the ore abraded by the shock, and so suddenly heated by the friction, as to be enabled to burn or combine with the oxygen of the air; and these sparks falling upon dry combustible matter, immediately cause it to do the same.

Fire, was the grand and idolized agent of the Alchemists; they discovered several methods of summoning it quickly into their presence, but these were confined to the mystic region of their laboratories, or only exhibited occasionally to astonish the unlearned and un-

initiated, who were obliged to rest content with employing the rude contrivances of their forefathers.

Modern Chemists have numerous methods of suddenly eliciting Fire; these are not kept as secrets, but are presented for the convenience of society, under the popular name of Instantaneous Lights, which are too well known to require a minute description.

Some of the instantaneous light matches contain the element phosphorus, which, by very slight friction, becomes hot enough to attract the oxygen of the air and burn with flame; others contain complicated compounds, which, by various means, are induced to exert a similar action; and all are so cheap, that there is no difficulty in obtaining Fire, either for chemical or domestic employment.

The Alchemists, had a favourite aphorism to the effect that without Fire they could not work; and indeed, so universal is the employment of this agent in the present state of science, that the Chemist is often called "The Philosopher by Fire."

Substances which kindle readily are popularly called combustible; some of them are

natural, and others artificial productions, and their burning or combustion is induced and supported by the oxygen of the air, which is called a supporter of combustion, because no ordinary fire or flame can burn without its presence.

There are many natural substances exceedingly combustible, such as wood, straw, flax, &c., yet the most intense heat of the sun is not sufficient to kindle them; if it were, dreadful conflagrations would be constantly taking place, and the labours of the husbandman would be in vain.

This is a fact highly illustrative of the great wisdom and goodness of the Creator, in providing an adjustment so accurate, between the temperature of the sun, and the vegetable productions of the earth, that they may be warmed and cherished, but never kindled and consumed by its powerful rays.

All natural combustible substances employed as sources of Fire, require the application of artificial heat before they will kindle; and the process of combustion, in all cases, may be defined as the exhibition of intense chemical affinity between the element or ele-

ments of the combustible substance, and some supporter of combustion, attended by the evolution of heat and light.

During combustion, no actual destruction of the elements of the combustible takes place; in fact, throughout the whole range of Chemistry, there cannot be found an instance of annihilation, but new, complex, and frequently invisible compounds are formed, which, when analysed, present their original elements unaltered.

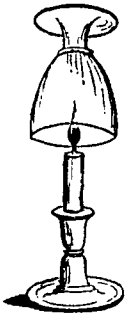
An examination of the phenomena which take place during the burning of a wax candle, will illustrate this matter to a certain extent.

Wax is a white solid substance, consisting of the elements Oxygen, Carbon, and Hydrogen; when fire is applied to the wick of a wax candle, the wax melts or becomes liquid; this changes into vapour, and kindles in consequence of the oxygen of the wax and of the air uniting with the carbon to form carbonic acid gas; and the hydrogen uniting with other portions of oxygen from both sources to form water.

These products, as they arise from the flame in a heated state, are quickly diffused through the surrounding air, and escape ordinary de-

tection; and this action continues until the candle is burnt out, or, chemically speaking, converted into carbonic acid and water.

The actual quantity or weight of these products can only be learned by the most refined experiments, but their mere presence can be detected by very simple means.



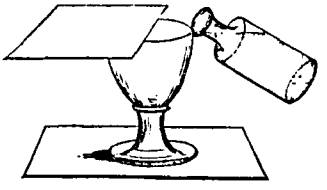
Let a clean, dry, cold glass tumbler be held over the flame of the candle for a minute, as here shown.

The heated vapour of the water which is evolving will be cooled and condensed like dew on its interior.

Remove the tumbler from over the flame, still with its mouth downwards, which close with a thick card, as here shown. This will prevent the invisible carbonic acid from escaping; and now the tumbler may be placed in its usual position on the table, with the card uppermost.

The card may then be drawn a little aside, so that a small quantity of clear lime-water

can be poured into the tumbler in the position here represented.



Cover the mouth of the tumbler again with the card; hold it firmly, whilst the tumbler is gently shaken, so as to agitate the lime-water, which will instantly become milk-white, because the lime, chemically attracts the invisible carbonic acid which the cold glass could not condense, as it did the vapour of the water, and a compound of carbonic acid, called a Carbonate of lime, is produced.

The Chemist, therefore, regards the cold glass as a test of the presence of the water, and the lime as a test of the carbonic acid, produced by the burning of the wax candle; and he can, by very refined methods, collect them both, extract the oxygen, hydrogen, and carbon, and prove that the united weight of these three elements equals that which the candle had before it was lighted; he, therefore, infers

that no destruction of matter has ensued during the combustion.

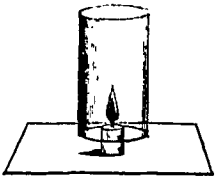
The beautiful pointed form of the candle flame is very remarkable, and it depends upon the air rushing around the candle to supply oxygen, becoming heated, and then rapidly ascending and drawing the flame in its track.

The pointed form of flame can be pleasingly exhibited by the following simple experiment. Let a ball of cotton, about the size of a walnut, be suspended from a very fine iron or copper wire, two feet long, then soaked in spirits of wine and lighted, a beautiful flame will be produced, as thus shown.

If the air were not rushing swiftly upwards to supply this flame, and, therefore, pressing more against the lower than the upper part of the ball; or, in other words, if the air were pressing equally all around, the flame would not appear thus: it would envelop the ball, and assume a spherical figure; but no flame can burn without disturbing the equilibrium of the air, as will fully appear hereafter.

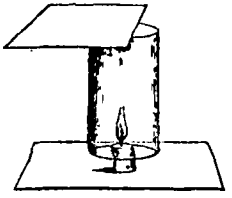
That the air does rush swiftly upwards and around a flame, and is absolutely necessary for its sustenance, that a flame becomes impaired or extinct by diminishing or preventing the access of air, may be rendered evident by a few simple experiments.

A short piece of wax candle may be lighted and placed upon the table, and a cylindrical lamp-glass held over it at a little distance from the surface of the table, as here shewn.



The air will now enter from the surface of the table through the lower part of the lamp-glass with freedom, and in quantity sufficient to maintain as bright a flame as the candle would burn with under ordinary circumstances, and thus coming to support the flame, yields its oxygen to the hydrogen and carbon of the wax, and then escapes at the top of the glass with the products of combustion, namely, watery vapour and carbonic acid, whilst fresh air enters below to perform a similar office;

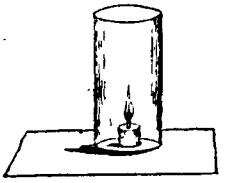
and thus the flame will continue burning with freedom.



Let the top of the lamp-glass be partially covered with a flat metal plate, rather more than here represented.

The flame becomes dim, because the air which has yielded oxygen cannot freely escape; and if the top of the lamp-glass be entirely covered, the flame dies, because the air is quite prevented from escape.

The glass remains full of burnt air, that is, of air contaminated with watery vapour and carbonic acid; and though the glass is still open below, no fresh air can enter whilst its interior is thus occupied.

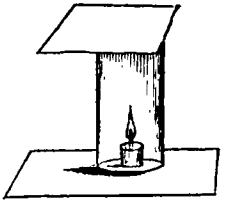


Let the candle be again lighted, and enclosed by the lamp glass standing on the table, and having its top uncovered, as here shown.

The flame still burns, though not with freedom, because the burnt air is endeavouring to ascend, and fresh air to descend through the

top of the glass; there is a struggle between the ascending and descending air, the flame cannot obtain its due share of the latter, and therefore burns languidly or fitfully.

If the top of the glass be closed, as here shown, the flame soon dies for absolute want of air, its own products being unfit for its support.

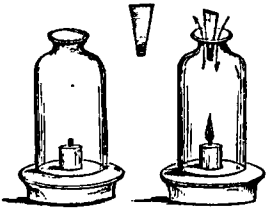


The following are beautiful experiments in illustration of the ascending and descending currents of burnt and fresh air.

On the centre of a flat and smooth piece of marble, wood, or slate, either circular or square, place a bit of common wax candle, one inch long, and light the wick. Take a glass, resembling in shape that of a bottle, the lower part of which is removed; this glass must be four inches in diameter, and seven inches high, and its neck three quarters of an inch internal diameter, and one inch long; the mouth or rim of the glass must be ground

smooth, and lightly anointed with pomade. Place the glass over the lighted candle, so that its rim may stand upon the flat marble, wood, or slate, press it slightly, that the surfaces may adhere closely.

The flame will soon languish and die, because the burnt air within the glass, and the fresh air without, struggle and neutralize each other in the narrow neck, and neither can escape nor enter. The figure on the left of the annexed engraving shows the form of the experiment.

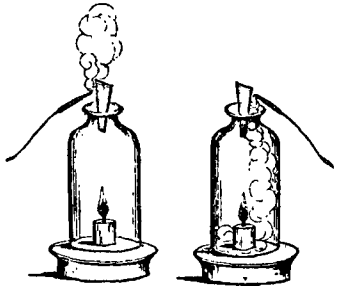


Remove the glass, re-light the candle, and place in the neck of the glass a flat piece of tin plate, four inches long, one inch wide at its upper, and half an inch wide at its lower part, so that it may stand exactly in the centre of the neck.

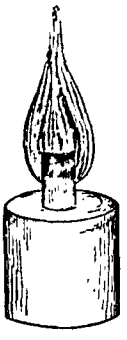
Place the glass over the flame as before, and it will continue burning with the same freedom as in the open air, for by this simple partition

the struggle of the ascending and descending currents is prevented, they are furnished with separate paths of exit and entrance; as shown by the arrows in the figure on the right side of the last engraving.

To detect these currents, let a small green wax taper, fastened to a wire handle, be lighted, and allowed to burn for a minute; then gently blow out its flame, so as to leave the wick smoking; apply the wick on one side of the partition, and if the burned air be ascending there, the smoke will ascend also; apply it on the other side, and if the fresh air be descending there, the smoke will descend with it. The arrangement is here represented.



Draw out the partition, and the flame will soon cease.



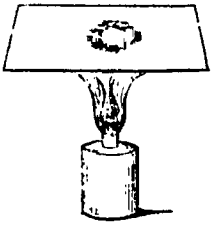
If the flame of a candle be examined, a dull spot will be noticed in its centre immediately above the wick, as shown in the accompanying figure.

The combustion of the vapour of the wax is superficial only, what is commonly called the candle flame, being in fact a mere film or shell, of white hot vapour, enclosing an interior portion, which cannot burn for want of air, and therefore evolves no light.

It appears strange to assert the absence of fire from the centre of the flame, but it may be proved by the following experiments, which can be made with facility.

Let half a sheet of the smallest note paper be held between the hands horizontally, and then suddenly lowered over the point of the candle flame, until it nearly touches the wick. Keep the paper there until it appears scorched upon its upper side, then remove it, and the scorch will be found as a ring or annulus, enclosing a spot of paper as white as the

rest of the half sheet; this effect is here represented.



The superficial ring or shell of the flame alone has scorched the paper, but the interior unburnt vapour has left a spot in the centre unharmed; this result could not ensue were the candle flame in complete combustion throughout.

Another experiment, illustrative of the above fact, may be made as follows.

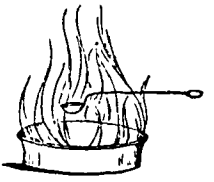
Pour a tea-spoonful of ether into a shallow tin cup, about four inches diameter and half an inch deep, kindle the vapour of the inflammable liquid by a slip of lighted paper, it will produce a large, beautiful bright flame; hold a long cedar pencil or other round piece of wood of the same size across the flame, close against the edge of the tin cup, it will be

scorched where it rests on the edge, by the superficial film of flame; but will remain unharmed in the centre. The arrangement will be understood from this sketch.

When the tin cup has cooled from this experiment, a similar quantity of ether may be poured into it, and kindled so as to obtain another large flame, and having put a piece of phosphorus, the size of a small pea, into a little ladle, it may be held near the point of the ether flame, and will soon burn with splendour.

If the ladle be brought down and fully plunged into the centre of the ether flame, the phosphorus will be extinguished, there being no air in the centre of the flame to support its combustion; but upon removing the ladle into the air the phosphorus will instantly burn. This experiment is an apparent anomaly of fire

extinguishing fire. The accompanying figure will explain the method of operating.



When the tin cup and ladle have cooled from this experiment, the latter must be washed with water, to remove a red residue which will be found in it; then, after it is wiped dry, the following experiment can be made, in further proof of the absence of air from the centre of a flame.

Take a piece of wax taper, about one inch long, press it into the ladle so as to stand upright, then kindle its wick.

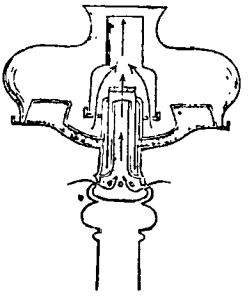
Pour a teaspoonful of ether into the tin cup, kindle the vapour of the ether by the lighted taper, remove it, until the ether flame burns vehemently, then plunge into it the burning taper, its flame will be extinguished.

These experiments prove that flame burning from a single wick, or a shallow surface, is a

mere film or shell of fire, enclosing unburnt vapour and exeluding air.

Hence, if a large oil flame be required, it will have a dark spot in its centre, and it will create much annoyance from the unburnt vapour passing off as smoke or soot.

In order to obtain a large brilliant oil flame, some contrivance is necessary for causing the air to come very plentifully and rapidly into the centre and around the exterior of the wick, so as to ensure complete combustion; this is admirably done in the Argand or dining-table lamp, a section of which is here presented.



A large ground glass shade is supported upon the rim of a hollow ring called the oil-cistern, from its lower part two small tubes proceed, into a larger upright double tube,

which rises a little above the level of the oil in the cistern.

This tube is constructed by placing one tube within another; the outer being connected with the tubes of the cistern, so that oil may flow into, and fill the space between it and the inner tube, which is connected with a perforated cup, attached to the pillar of the lamp.

In the oil of the outer tube a cylindrical cotton wick is immersed, and when kindled it is surrounded by a cylindrical glass, supported upon a perforated ring or gallery attached to the outer tube.

The glass is not of equal diameter throughout, but is contracted near the flame.

Thus arranged, the flame will burn with great brilliancy and without smoke, because the air necessary for the combustion of the vapour of the oil enters simultaneously through the perforations of the cup to the interior circle, and through those of the gallery to the exterior circle of the wick, and the contraction of the glass causes the air to rush against the flame, to ensure its perfection; the direction of the air is shown by the small darts.

No dark spot will be observed in the pro-

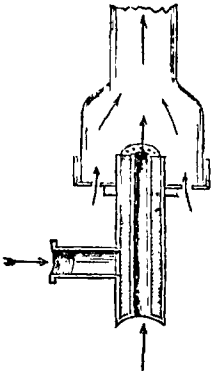
perly-regulated flame of the Argand lamp, because all the combustible matter is consumed; the height of the wick is regulated by turning the gallery right or left, for there is a wire connected with it, that passes to a ring at the bottom of the wick, so that it may be elevated or depressed; this is not shown in the engraving, as it would complicate the description.

Whilst the flame is burning with brilliancy, let a cloth be folded around the cup, so as to cover the perforations and prevent the entrance of air to the interior of the flame; it will instantly become dull and smoky, because the air which is yet rushing to its exterior through the perforations of the gallery is insufficient to consume all the vapour produced by the wick; a great portion escapes unburnt as black soot; remove the cloth and the flame will resume its brilliancy.

The use of the cup is to receive any excess of oil that may drop away from the wick, and if this be not removed when the lamp is trimmed, it will accumulate and stop the perforations, and the flame will burn dull and smoky.

The Argand-gas burner for consuming coal-

gas is generally made about the same size as that of the dining-table lamp, and is similar to it in principle, though slightly modified in form to suit the peculiar nature of the combustible gas, which, being already vapourous or aeriform, requires no wick.



This contrivance is here represented in section.

It consists of two tubes, the one within the other, as already described; below they are united closely by a ring, and above by a ring pierced with twelve or fourteen holes, not larger than will admit a fine sewing needle: a tube at right angles is connected with the lower part of the outer tube, a cylindrical glass, contracted as before, is supported on a perforated gallery attached near the middle of the burner.

The tube at right angles is connected with the gas pipe of supply, the gas rushes through it in the direction of the feathered dart, fills

the space between the tubes, escapes through the small holes, and is kindled by a lighted paper held over the glass; and by regulating the admission of the gas, a brilliant flame without smoke may be obtained, because the air rushes simultaneously through the centre of the burner and the perforations of the gallery, and consumes all the combustible matter.

The direction of the air is shown by the featherless darts; stop its admission to the inner ring by thrusting a cork into the lower aperture of the burner, and the flame will become dull and smoky; remove the cork, and the flame will regain its brilliancy.

The glass is represented of the same shape as that of the dining-table lamp, but it may be equally cylindrical throughout, as that employed in the experiment at page 25, because the gas rushes with great velocity through the small holes, and in burning compels the air to follow its course upwards, more peremptorily than the oil-vapour flame can do, it being only slowly produced, and therefore for it the glass must be contracted in order to thrust the air against the flame, and compel it

to yield effectual support before ascending with the products of combustion.

The cause of the light of flame is the next object of inquiry.

Flame is volatile matter heated so as to become luminous. The light evolved is in proportion to the quantity of solid matter present in the combustible, and the following experiments will support this definition of flame.

The element called Hydrogen, which has been already mentioned, is a gaseous inflammable substance, whose properties will be more particularly discussed hereafter, but its combustion may be now adduced as an example of the purest form of flame.

Hydrogen gas may be evolved in the following manner: place an ounce of small fragments of the metal zinc, in a wide-mouthed pint bottle; dilute two fluid ounces of sulphuric acid, with four ounces of water, in an earthen jug; this must be done by adding the acid very gradually to the water, and stirring them together with a piece of wood or a glass rod; the mixture becomes very hot; it must be allowed to cool, and then one half is to be

poured into the bottle containing the zinc; a brisk effervescence ensues, which is due to the evolution of hydrogen, the mouth of the bottle is then to be closed with a cork through which passes a brass tube nine inches long and rather more than a quarter of an inch diameter at its lower end, and so small at the other as only to admit of the entrance of a large sewing needle; the appparatus is here shown. Permit the effervescence to continue for about three minutes, then hold a lighted slip of paper to the small aperture of the brass tube, and the hydrogen which is thence escaping will kindle and burn with a pale flame, until the effervescence ceases; the liquid in the bottle may be then thrown away, and the remainder of the acid added to the zinc, so as to evolve more hydrogen if it be required.

The pale flame of hydrogen is scarcely visible in broad daylight, and is invisible in bright sunshine; it is a type of pure flame, containing no solid matter, producing no solid

matter, but only the vapour of water by uniting with the oxygen of the air, as will be shown in future experiments; and if the flame be tested by the cold glass tumbler and the lime-water, as at page 23, the deposition of water like dew will be remarked, but no carbonate of lime will appear as in the former experiments.

The flame of hydrogen, though exceedingly pale, is intensely hot, as may be proved by a simple experiment. Take a platinum wire, twelve or fourteen inches long, and as fine as ordinary sewing cotton, tangle it into a flat knot, leaving only two inches straight; hold this, and place the knot in the flame of the hydrogen, the platinum will become white hot, and glow with great brilliancy; but it does not consume; it will be found unaltered after the experiment.

The terms Ignition and Combustion are commonly regarded as synonymous, but they denote two perfectly distinct phenomena. Ignition, (from the Latin *ignis*, fire,) is the evolution of light from a solid body, at an elevated temperature; it is neither necessarily attended by change of form nor new products. The

white hot platinum wire is an example of pure Ignition, and it will exhibit the same curious phenomena at any future time. Combustion, (from the Latin *comburo*, to burn,) is the evolution of heat and light from a body necessarily attended by change of form and new products; or, it may be defined as a manifestation of intense chemical affinity between two or more bodies, attended by the evolution of heat and light, and the production of new compounds. The flame of hydrogen is an example of pure Combustion or affinity between the evolving hydrogen, and the oxygen of the air; the two elements combining to produce the compound called water.

It is true that many substances undergo temporary ignition previous to combustion, and upon this fact is founded an explanation of the great light of common flames; for example, instead of holding the platinum wire in the flame, as above described, let a little fine charcoal dust be shaken through the flame, and light nearly equal to that of a candle is instantly evolved.

The charcoal is solid matter, and also combustible matter, therefore the intense heat of

the hydrogen flame momentarily ignites it, in which heated state it exerts affinity for the oxygen of the air, and then burns. Light is elicited from the ignition and from the combustion, the result of which is carbonic acid gas.

Another experiment, proving the evolution of great light, by the introduction of solid combustible matter into a pale flame, may be made with the contrivance represented in the accompanying sketch.

It consists of a taper wooden or metallic handle, twelve or fourteen inches long, one inch diameter at its lower end, and one inch and a half diameter at its upper end, to which is attached a conical tin box, four inches diameter and two inches deep. This box is provided with a cover, having small pin-holes near its circumference, and a ring two inches diameter, and half an inch deep in its centre, to hold a sponge, which is secured by a wire thrust across. The box is filled with finely-powdered-resin, the cover placed on, the sponge is then soaked in spirits

of wine, and kindled; it will burn with a very pale blue flame, because no solid matter is produced by the combustion, but only carbonic acid and water. Let the handle be held firmly, and suddenly shaken so as to dust the powdered resin through the flame, a large flash, or rather blaze, of vivid light will be evolved by the instantaneous ignition and combustion of the solid inflammable matter, and much black smoke will accompany the blaze, as the whole of the carbon of the resin does not perfectly consume.

This contrivance is employed in theatres for imitating the sudden flash of lightning, but instead of resin the box is filled with a very fine combustible powder, called Lycopodium, from the Greek λύκος, a wolf, and πόδὸς, a foot; it is the seed of a species of Club moss, which bears some resemblance to the foot, or paw of a wolf. Lycopodium, shaken through the spirit flame, flashes more instantaneously and vehemently than resin, but entirely consumes, so that the performer is not annoyed by smoke.

In the wax, tallow, or oil employed as sources of light in candles and lamps, the elements

Hydrogen, and Carbon, or Charcoal, are combined by some wonderful power of Nature; and the action which ensues when these combustibles are heated so as to produce flame, may be stated as follows.

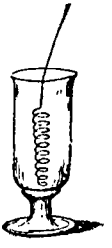
Hydrogen being the most inflammable element, kindles first, whilst the Carbon with which it was united, is liberated in a most minutely divided solid state throughout the flame, momentarily ignited to whiteness, and then burned; and being thus constantly showered through the flame, great and steady light is emitted.

For all purposes of illumination, it is essential that the light of flames should resemble sun light, in consisting of the seven primary colours, namely, Red, Orange, Yellow, Green, Blue, Indigo, and Violet; but artificial light is seldom perfect in this respect, and accordingly candlelight is unsuited for the true display of colours, it generally containing excess of yellow rays. A most curious effect may be produced by illuminating an apartment with yellow light, which can be commanded as follows. Let a tin dish, twelve inches diameter, and half an inch deep, be supported on

a tripod over a spirit-lamp, as here shown.

Pour into the dish two fluid ounces of spirits of wine, and one ounce of water; kindle the flame of the lamp, and darken the apartment: then hold a lighted slip of paper, so as to kindle the vapour of the heated spirits in the dish, and throw into it at the same time a handful of common salt, and stir it with a thick iron wire. Yellow light is abundantly evolved, and it will show no objects in the apartment of their proper colours, excepting such as can reflect yellow light. The most brilliant red and blue drapery, flowers, &c., appear dingy, or black, the countenances of all in the apartment assume a livid ghastly hue; but if in this state of things a handful of Lycopodium be thrown into the flame, its combustion emits white light, and at the instant of the flash every object appears of its true colours.

Flame requires great heat for its existence; and although spirits of wine, turpentine, and ether are popularly called exceedingly inflammable substances, they will not burn until heated to whiteness; ether is the best that can be employed to prove this fact, in the following manner. Take a fine platinum wire, about the size of that at page 41, and eighteen inches long; coil it around a cedar drawing pencil, so that upon removal it will form a spiral, as represented in the engraving. Let a teaspoonful of ether be poured into a tall ale-glass, and in the course of a minute it will become filled with the vapour of the volatile liquid. Hold the straight end of the platinum wire, so that the flame of a spirit-lamp may heat the spiral red-hot; then remove it, and quickly plunge it into the glass, so as nearly to touch the ether, as here represented. The spiral will continue glowing red-hot, but the vapour of the ether will not inflame until, as often happens, the spiral increases its heat to whiteness; so long



as it remains merely red-hot, the ether is induced slowly to change its characters, and exert affinity for the oxygen of the air; in fact, it is consuming without flame; but when the spiral becomes fairly white hot, the affinity of thee thereal elements for the oxygen is hurried, and the ether burns with a luminous flame. This beautiful experiment proves that flame requires great heat for its existence: and one very familiar example of this may be here adduced.

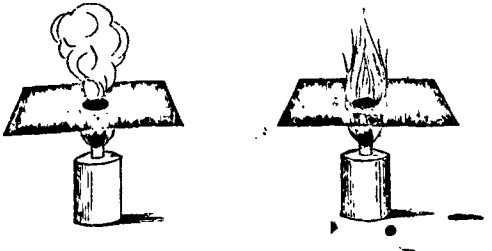
Let the wick of a candle be lighted, and the flame allowed to burn until the wick is nearly as high as the flame; then let it be blown out, and although the wick remains red-hot and glowing, it is not sufficiently hot to inflame the vapour of the wax or tallow which is yet rising like a smoke. Let a slip of lighted paper be held in the ascending vapour, about one inch from the top of the wick; it will instantly inflame, by the white heat of the burning paper, and suddenly flash down to the glowing wick, so that it is rekindled, and combustion proceeds as usual.

Neither wax, tallow, spermaceti, nor oil, can be inflamed without being converted into

vapour; and this is effected by the red-hot wicks of the candles or lamps, in which these sources of light are arranged for combustion.

As flame requires so much heat for its existence, it follows that if cooled by any means it will become extinct; and this can be shown by holding a piece of fine metallic wire gauze over the point of a large candle flame, until it nearly touches the wick; the flame will not pass through the meshes of the wire gauze, because the metal of which it is woven carries off, or conducts away, the heat with such quickness, as to cool down the inflammable vapour so low that it cannot burn; it is, however, passing through the gauze unburnt, and may be kindled there by a slip of lighted paper.

These two experiments will be understood from the annexed figures.



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Camphor is an inflammable volatile substance; and if a piece of it be placed on the centre of the wire gauze, and held over the flame of a candle, the vapour of the camphor produced by the heat will pass downwards through the gauze, and kindle at the flame, whilst the remaining solid camphor will not burn, because neither the candle flame nor the camphor vapour flame can pass through the meshes.

The safety-lamp for coal miners, or the Davy lamp, as they call it, in gratitude to the inventor, depends for its value and utility upon the fact of flame being unable to pass through the meshes of wire gauze.

During the hazardous operations of mining for coal, especially in the northern counties of Britain, a large quantity of inflammable gas, very closely allied in chemical nature to that employed for lighting streets and buildings, frequently rushes forth from cavities in the earth, and mingling with the air of the mine, forms an atmosphere which kindles at the flame of the miner's candle, and produces a most terrific explosion, which is generally attended by dreadful loss of human life.

The miners call this gaseous exhalation The Fire-Damp, and were unable to avert its destructive effects until the invention of the safety-lamp by the late Sir Humphry Davy, the form of which is here represented. It consists of a cylinder of iron wire gauze, with a double top, securely fastened to a brass rim, which screws on to the lamp; it is protected and made portable by the stout wire frame, and ring handle; at one side of the lamp is a tube for supplying oil without unscrewing the cage; this is closed by a metal stopper, fastened by a chain to the lamp, that it may not be lost; and through the bottom of the lamp a wire passes in an air-tight tube; the wire is bent at right angles at each extremity, so that by moving the lower to and fro, the upper extremity removes the snuff from the wick, or by sticking into it, raises or lowers it according as required.

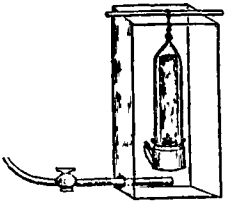
The lamp being properly trimmed, the wick lighted, and its flame imprisoned in the cage, it will continue burning with safety; and even

if the lamp be thrown on one side, so that the flame may play against the wire gauze, yet it will not pass through, for the reason above given.

If the safety-lamp be taken into a coal mine containing fire-damp, a portion of it instantly rushes through the wire gauze to the flame, and burns within the cage, but cannot emerge from thence as flame, to explode the whole contents of the mine, because in the attempt the wire gauze cools it down; and thus the miner is enabled to consume his dangerous enemy; and by watching the changes of colour which the flame of the lamp undergoes, he is enabled to judge of the quantity of fire-damp around him; at times this is so great, that the wire gauze cage becomes red-hot by the intense combustion within it; and then he knows that he is on the verge of danger; for if the heat rise much higher, the flame will pass, because the wire can no longer cool it; therefore, for safety, the lamp must be screened from the direct rush of the fire-damp, or taken away, until the mine is ventilated.

The security of the safety lamp may be shown upon a small scale very easily, in the

following manner, if coal gas can be obtained. Provide a box, six inches square, and eighteen inches high, having a hole half an inch in diameter, pierced through one side near the bottom; and in this place a small pipe, connected with the gas pipe of the apartment; light the wick of the lamp, screw down the cage securely, and then suspend it in the box, as here represented.

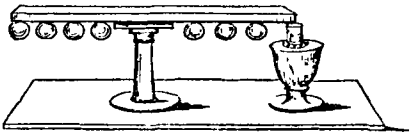


The flame will continue burning, as in the open air; but upon gradually turning on the coal gas, which mixes with the air in the box, and forms an explosive medium, the flame enlarges, and is then extinguished, the cage being filled with a flickering lambent blue light, due to the combustion of the imprisoned gas, which cannot escape as flame to kindle the surrounding mixture. Upon turning off the supply of gas, the wick of the lamp rekindles upon re-

admitting it, the appearances again ensue, and if a lighted taper be introduced into the box, an explosion takes place.

If coal gas cannot be procured, the air in the box may be rendered explosive by the introduction of a table-spoonful of ether, the lamp will burn in it with safety; but an unprotected flame will cause an explosion.

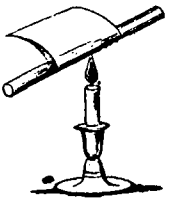
In all these experiments upon the temperature of flame, the heat is carried away by the metal of the wire gauze; and in chemical language all metals are said to conduct heat; thus, if one end of a bar of metal, such as the steel poker, be placed in the fire, and the other held in the hand, the heat gradually travels from one end to the other, and the hand cannot endure it after some time; this is a familiar example of the conducting power of metal; and the progress of the heat throughout a metallic bar may be strikingly illustrated by the accompanying arrangement.



This represents a bar of iron, eighteen inches

long, and three quarters of an inch square, supported at its centre upon a wooden column; to the under surface of the bar are attached, at regular intervals, by a little wax or pomade, a number of balls or marbles; a lighted lamp is placed beneath one end of the bar, and as it conducts the heat, the wax melts, and the balls drop off in succession; thus showing that the conduction of heat by the metal is progressive, and not instantaneous.

If a copper bar of similar dimensions be experimented upon, the balls will drop off more rapidly, because copper is a better conductor of heat than iron; no two metals exactly agree in conducting power. Let a cylindrical bar of iron, copper, or brass, twelve inches long and one inch diameter, highly polished, be enveloped tightly in half a sheet of thin writing-paper, and held as here shown, so that the flame of a candle may touch the paper.



The paper will only blacken by the smoke, it will not scorch in the least degree, because the heat, as it impinges upon the paper, is conducted away from it by the metal beneath, with such velocity as to be incapable of accumulating and burning the paper; but let a similar sized bar of wood be substituted for that of metal, and the paper will burn immediately, because the wood cannot conduct the heat from the point upon which it impinges.

Metals are the best conductors of heat, whilst wood, stone, and earths are the worst. A very striking instance of the bad conducting power of sand occurred at the siege of Gibraltar.

The red-hot balls used during the engagement were carried from the furnaces in which they had been heated, to the bastions upon layers of sand in wooden barrows, and this effectually prevented the heat from passing to the wood and setting it on fire.

The bad conducting power of sand may be illustrated by filling the palm of the hand with a heap of perfectly dry white sand, upon this a red hot iron ball, the size of a small orange, may be placed, and borne for some

time without inconvenience. The annexed drawing shows the form of this remarkable experiment.

The action of Fire and heat upon the three remaining Ancient Elements, Air, Earth, and Water, is productive of the most remarkable and important changes, which will demand particular attention; in this Chapter, the means of eliciting Fire, the nature of flame, and the conduction of heat, have been discussed, as introductory to other properties of this grand agent of the ancient and modern Chemist.

CHAPTER II.

AIR.

GREEK, αηρ; LATIN, *aer*; FRENCH, *air*.

AN inquiry regarding the chemical nature of Air, will present information having intimate connexion with Fire, Earth, and Water.

The Ancient Element Air, is also called The Atmosphere, from the Greek ἀτμὸς, *vapour*, and σφαῖρα, *a sphere*.

As it is a transparent, invisible medium, or ambient mantle, by which the Earth is enveloped, and accompanied during its axial and orbitual revolutions.

The direct altitude of the atmosphere from the surface of the Earth, has not been experimentally ascertained; it is conjectured to be fifty miles; and though this strikes the mind as a vast extent, it bears a very small propor-

tion to the gigantic diameter of the Earth, which is eight thousand miles.

The atmosphere, therefore, is a mere film around the Earth; and for the sake of illustration let an artificial globe, twenty inches diameter, represent the Earth; then a case, one-tenth of an inch thick, enveloping it, would nearly denote the Atmosphere.

The total weight of the atmosphere has been ascertained, and it is expressed by the incomprehensibly enormous sum of five quatrillions, two hundred and eighty-seven trillions, three hundred and fifty billions of tons; a weight nearly equal to that which a solid globe of lead would have, if sixty miles diameter.

The experimental evidence upon which this startling fact is established, will be partly described hereafter; suffice it now to state, that Air, though invisible, can be weighed and measured with almost the same facility as solids or liquids; so can all gases and vapours; the only agents which elude the test of the balance, and all ordinary methods of measurement and confinement, are, Light, Heat, and Electricity; they are accordingly styled Im-

ponderable Elements; but they exert more or less influence upon every kind of Ponderable matter.

Air is essential to the life of animals and vegetables, also to the existence of ordinary combustion; for deprived of air, no creature can breathe, no plant can grow, no fire can burn.

Air is everywhere present upon the Earth, and all vessels which are commonly regarded empty, are in truth full of air; this fact may be proved by very simple experiments.

Let a large finger-glass be nearly filled with water; then let a small wine-glass be held with its brim downwards, to touch the surface of the water, as here shewn.

Let the wine-glass be pressed through the water, to touch the bottom of the finger-glass, as thus represented.

The water will not enter the wine-glass, because it is full of Air which has no means of escape; if the wine-glass were empty, then should the water fill it, but let it be carefully lifted from the water, and examined, whilst held with the brim downwards, and its interior will be found dry.

Upon the water in the finger-glass float a thin slice of cork, and upon this carefully place a small beetle; cover both with the wine-glass, then press it down to the bottom of the finger-glass as before.

The upper surface of the cork and the insect will remain dry; and if the wine-glass be steadily lifted, the cork and its tiny freight will follow to the surface, where, upon removing the wine-glass, the cork may be lifted from the water, and the beetle liberated unharmed.

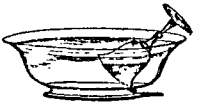
These simple proceedings illustrate the principle of a wonderful invention called The Diving-Bell; it is a strong vessel, constructed of cast-iron, in the form of a bell, sufficiently capacious to admit of several persons being seated upon a circular bench, near the lower part or brim of its interior.

The diving-bell, thus freighted with human

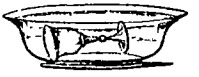
beings, is lowered by proper machinery into the waters of the ocean, so that great depths may be thus explored, submarine works carried on, and sunken treasure recovered.

Although the diving-bell contains a very large quantity of air, this is not adequate for the long-continued respiration of those who descend in it, (as that in the wine-glass was for the life of the insect,) and therefore a constant supply of fresh air is introduced, by means of forcing pumps placed near the surface of the water, and communicating with the interior of the diving-bell by long flexible tubes; but a description of this mechanical apparatus does not belong to the present inquiry; the simple means which led to this notice may be now resumed for other experiments.

Hold the wine-glass with its brim touching the surface of the water, and press it down as before; then move the wine-glass into a slanting position, as here shown.



Part of the air will immediately bubble through the water, whilst a portion of water will enter, to supply the place of the escaped air; move the wine-glass into an horizontal position, all the air will escape, and its interior will be filled with water.



These two experiments, in conjunction with the others, form the basis of an extensive department of Chemistry relating to operations upon air and gases; they will be adverted to in future pages; at present they have served to illustrate the presence of air in a vessel commonly regarded empty.

The enormous weight of the atmosphere is not felt by man and animals, because all are perfectly enveloped by it, and its weight or pressure is everywhere equal; for the same reason, fishes are insensible of the yet more enormous weight of the ocean in which they are immersed.

Man and animals move throughout the air with as much facility as fishes glide through

out the water; the delicate thistle-down is not crushed by the atmosphere, nor the fragile sea-weed torn by the wave, because both are supported equally on all sides by their respective Ancient Elements.

If the natural equilibrium of the air be disturbed, its weight or pressure becomes manifest, and each gallon of air is found to weigh about one hundred and twenty grains, or a quarter of an ounce.

There are several agents by which the equilibrium of the air may be disturbed, so as to render its weight or pressure manifest, but the simplest that can be employed is Fire, or Heat.

Let a wine-glass be held over the candle flame for a moment, as thus; then suddenly remove it, with its brim downwards, which close with the palm of the hand; the wine-glass will adhere strongly, and will not fall off, even if the hand be moved into an opposite position; considerable force will be required to separate it, and when separated, it will not adhere

again, without it be held over the flame as before.

The explanation of the experiment is simple; the heat of the flame suddenly expands, or drives forth the greater portion of air from the glass; the palm of the hand then closes its mouth, and excludes the surrounding air of the room, the pressure of which air, endeavouring to enter, causes the mutual adhesion of the glass and the hand.

The experiment may be thus modified. Let the mouth of a thick glass tumbler be accurately ground smooth, apply a little pomade to this surface, place the tumbler with its mouth against a flat piece of plate-glass, the two will only adhere by the tenacity of the pomade, and can be easily separated, because they are both in equilibrium.

Let the flame of a spirit lamp be allowed to burn for a moment in the tumbler, held with its mouth downwards, then remove it and apply its mouth to the plate-glass, a mutual adhesion will take place, for the reason already described, and so strongly that by holding the foot of the tumbler, the plate-glass may be lifted without danger of falling away; a very considerable pull

will be required to separate the two, and then the air will enter the glass with a slight noise, to restore the equilibrium.

In these experiments if the glasses were not strong enough to resist the external pressure of the air, they would be crushed to atoms by its force; but all ordinary wine-glasses and tumblers are sufficiently thick, so that no danger need be apprehended from their use.

The crushing or destruction of a vessel insufficient to resist the pressure of the air may be safely exemplified by the following arrangement.

This represents a cylindrical canister, constructed of very thin tin-plate, its dimensions being twelve inches long, and five inches diameter; its seams, bottom, and top are all closely soldered; but in the centre of the latter is an

aperture three quarters of an inch diameter, into which is soldered an open tin tube, four inches long; a sound French cork must be accurately fitted to this, and then removed.

Around the tin tube a strip of thick woollen cloth is wound and tied, to form a handle by which the canister may be lifted, without injuring the fingers by the heat of the steam, to be produced as follows.

Let a tea-cup full of water be poured into the canister, and a lighted lamp set beneath, so that the water may boil rapidly, its steam will expel the air from the canister through the tube; when steam issues abundantly, remove the canister from the flame, and instantly thrust the cork into the tube.

The steam will cool or condense into water, no air can enter to supply its place, because the vessel is tightly soldered and corked, but the air is endeavouring to enter, and the canister, being unable to resist the pressure, will be crushed together with great force.

The degree of expansion which air sustains by the action of heat can be determined in an

experiment, the form of which is here represented.

It consists of a glass bulb, two inches diameter, blown at the end of a glass tube, one quarter of an inch in the bore, and eighteen inches long, the bulb and the tube contain air, the glass contains water, into which the of end the tube is deeply immersed.

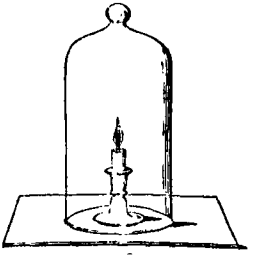
The air thus confined, is yet in equilibrium with that of the apartment, and has no tendency to escape: apply the flame of a spirit lamp gently to the bulb, and the air within it will expand instantly, and several bubbles will escape through the water.

Remove the flame, and a portion of air which the bulb yet contains, will cool and undergo contraction, and if the end of the tube were not under water, air from the room would enter to supply the place of that expelled by the heat; but, as it is under water, the air cannot enter, it therefore exerts pressure upon the surface, and forces a portion of water upwards in the tube as its substitute, in quantity exactly proportionate to that of the air expelled by the heat.

The air will expand again if heated, and contract again if cooled, for any number of times; and if the heat be continued, the greater part of the air will escape, and upon cooling, the bulb will be nearly filled with water; but it is likely to break in the experiment.

Air is a Mixture of Nitrogen and Oxygen gases; mere heating and cooling does not affect its composition, but actual combustion withdraws Oxygen, produces Carbonic acid gas, Watery vapour, and liberates elementary Nitrogen; these all escape in the open air, and combustion proceeds freely, because fresh air has access to the flame, but when confined they accumulate and extinguish it, and constitute the "burnt air" of the experiment at page 27.

Place a lighted candle upon the table, cover it with a large glass shade, as here shown.

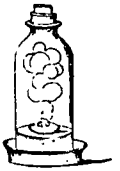


The flame will continue brilliant for a short time, then grow dim, flutter, and ultimately expire; and notwithstanding more air is present than in glass at page 27, it contains but a limited quantity of Oxygen, and when the Carbon and Hydrogen of the wax have united with this to form Carbonic acid gas and Watery vapour, these Compounds and the remaining Element, Nitrogen, having no means of escape, the flame cannot continue for want of fresh Oxygen; or, in other words, Chemical affinity ceases, Nitrogen having no affinity for Carbon and Hydrogen under these circumstances.

An examination of the Elements of the air will afford some information regarding the operation of Analysis, a term derived from the Greek ἀνά, thoroughly, and λύω, to unbind. The action of the highly combustible element Phosphorus, upon a confined portion of air, is resorted to in order thoroughly to unbind or separate the Nitrogen from the Oxygen.

Place a piece of Phosphorus the size of a pea in a small saucer, floating on water contained in a deep plate, touch the phosphorus with a hot wire, and it will burn brilliantly; let it then

be covered with a two quart stoppered bell-glass, which, of course, contains air, and the combustion will continue for some time, but at length cease, as that of the candle did in a former experiment.



The glass now appears full of white fume, which gradually vanishes, and water rises from the plate into the glass, indicating that something has been taken from the air by the phosphorus. The theory of the operation consists in the Phosphorus combining with the Oxygen of the air to produce Phosphoric acid, the white fume which dissolves in the water, whilst having no affinity for the other element of the air, namely, the Nitrogen, that remains in the glass. Thus, the air is analysed, and the proportion of Oxygen which has combined with the Phosphorus, is indicated with some accuracy by the quantity of water which has risen in the glass to supply its absence.

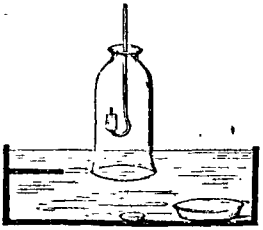
The aeriform substance or gas remaining in the glass, is as transparent and invisible as the air itself was before the experiment; but it is very different in chemical nature. It will not support flame, and this is at once evident by

the highly inflammable phosphorus ceasing to burn when it has abstracted the whole of the Oxygen, that is, about one-fifth of the original bulk of the air, or the fact of Nitrogen being a non-supporter of combustion, may be yet further proved by introducing the flame of a taper in the following manner.

The plate, with the bell-glass standing in it, must be lifted and quite immersed beneath the surface of water contained in a shallow tub or trough, and allowed to fall to the bottom, whilst the bell-glass is supported by the hand and shaken slightly to splash a little water into the floating saucer, and so cause it to sink; this being done, the bell-glass must be sunk so that the level of the water within it coincides with that in the trough, the stopper may then be removed, and a lighted taper attached to the end of a wire plunged into the gas; the flame will be extinguished as perfectly as though it were dipped into the water.

The accompanying sketch exhibits the requisite arrangement, and it is convenient to have a small wooden shelf fixed at one end of the trough, an inch and a half beneath the water, that the bell-glass, and other glasses to

be spoken of, may be occasionally supported upon it, to relieve the hands of the operator.



A small animal, or bird, put into Nitrogen would die instantly, but there is no occasion to mar the pure pleasures of Chemistry by such a wanton and cruel experiment, as the fact is established beyond a doubt, and it may be laid down as a general rule, that where a taper cannot burn, an animal cannot breathe.

The gaseous element thus destructive of life and flame is sometimes called Azote, from the Greek ἀ, not, and ζωή, life, but it is more commonly called Nitrogen, from νιτρον, nitre, and γενω, to generate, because under certain conditions it generates Nitre.

The word Gas, is of German origin, implying spirit or essence, and it is generally borne by all aeriform matters which are unalterable by pressure or cold, such is Nitrogen, and as it

cannot be analysed it must be regarded as one of the Elements of the Air: it presents the chemist with a perfect specimen of a non-supporter of combustion, and of an incombustible substance; for although there are many combustible elements and compounds, none of them will burn in Nitrogen, nor will it burn under any circumstances.

A search after the principle or element of Air which does support combustion is rather difficult, because no agent has been discovered capable of taking away Nitrogen and leaving Oxygen; and therefore what Chemists call indirect action must be employed.

In the last experiment, the Phosphorus took away Oxygen from the air to form the compound called Phosphoric Acid, and there are methods by which oxygen may be taken in turn from this and exhibited in a pure state; but as these are rather too difficult and abstruse for mention here, other agents must be called into action, and even with them the operation will not be so directly evident, as that of the phosphorus leaving the nitrogen, but the following experiment will serve as preparatory to the matter in question.

If a lump of bright lead be melted in a ladle on the fire, and kept in that state for some time, it tarnishes, and becomes encrusted with an earthy-looking powder; indeed the Alchemists thought that the metal was really transmuted into earth; but the theory of this change of metallic lustre consists in the melted lead exerting affinity for the oxygen of the air, and slowly burning and producing a compound with the oxygen, called Oxide of lead, which is the powder alluded to above.

Many other metals thus tarnish or oxidize. Mercury does so in a most remarkable manner; its oxide is commonly known as Red Precipitate, in allusion to its colour, and its falling against the side of the vessel in which it is prepared.

This compound or Oxide of mercury is preferable to that of any other metal as a source of oxygen, for if it be made red-hot, the affinity between the mercury and the oxygen is overcome by the heat, or, in other words, the oxide is decomposed or analysed, and its elements may be obtained in their pure forms; the Mercury as a bright fluid metal, the Oxygen as a transparent invisible gas.

This curious and instructive experiment may

be conducted by placing an ounce of oxide of mercury in the bulb of a two-ounce green glass retort, (the word retort is derived from the Latin *re*, back, and *torqueo*, to twist, because the neck of the vessel is bent nearly at a right angle,) the beak or end of which is then arranged so as to dip two inches below the surface of the water contained in the trough, which was used in a former experiment, whilst the bulb is supported on a metal ring, which slides along a metal rod, placed on a heavy foot, and called a retort-stand; the ring has a screw by which it may be adjusted at any height.

A small clear glowing charcoal fire, contained in a chafing-dish or crucible furnace, is then to be placed beneath the bulb of the retort, so as to heat it very gradually.

The arrangement is shown in the accompanying sketch, as well as a part to be mentioned in the ensuing pages.

The heat of the charcoal fire immediately causes the escape of numerous small bubbles from the beak of the retort, through the water, as in the experiment with the glass bulb and lamp, at page 68, and for the same reason; but these bubbles of air will cease in a few minutes.

As the retort becomes hotter, other bubbles will escape, at the same time that a grey film adheres to the arch or larger part of the neck of the retort, which was quite clean at the outset of the experiment.

These appearances announce the evolution of Oxygen gas, which may be collected by taking a pint glass bottle having a wide mouth and ground stopper, applying a slight touch of pomade to the ground part, and then turning it round in the neck once or twice, so as to distribute the pomade between the ground surfaces, in order that there may be no difficulty in removing the stopper for the experiment to follow, and also to prevent the escape of the gas with which the bottle is to be filled.

The stopper may now be removed, and the bottle sunk in the trough, with its mouth upwards, so that the air may entirely escape and

water take its place; this being done, the bottle must be turned mouth downwards and steadily lifted until exactly over the beak of the retort from whence the bubbles are issuing; the bottle may be conveniently supported on the shelf of the trough, over a hole made in it an inch in diameter, beneath which hole the beak of the retort is placed; the bubbles will rise through the water in the bottle, whilst the water falls into that contained in the trough.

By this simple arrangement, the Chemist collects the greater number of gases with which he is acquainted; and whilst the operation is proceeding, the charcoal fire requires replenishing, to keep the bulb of the retort nearly red hot, which may be done without danger of melting the glass; the grey film already noticed will increase and separate into minute brilliant globules of Mercury, many of which will run down the neck of the retort, and fall to the bottom of the water in the trough.

Thus both Elements of the oxide are obtained, and when the bottle is quite full of Oxygen it must be moved off the shelf very steadily, still with its mouth downwards, and under water, in which position the stopper is

to be inserted by dipping the fingers between which it is held under water; the gas is now effectually confined, and the bottle may be removed, whilst another can be filled in like manner and so on until the whole of the oxide is decomposed; the beak of the retort may then be removed from the trough, and the operation is finished.

The properties of Oxygen gas are now to be examined, and more especially its power of supporting flame; having lighted a paper allumette, the stopper of a bottle containing the gas is to be removed as it stands on the table, and the lighted paper thrust into the gas for an instant; it will burn with more intensity and brilliancy than in a similar sized bottle full of air; if it now be removed and its flame blown out, and again quickly thrust into the gas, whilst a red hot spark remains on the paper cinder, it will be rekindled, and this proves that Oxygen gas not only supports, but induces flame.

Oxygen gas in this respect is diametrically opposed to Nitrogen; it also supports animal life for a short time, but ultimately proves fatal: and a fact well worthy of remembrance

here demands attention, namely, though Chemists have discovered many gases, and compounds and mixtures of gases which may be inhaled for a time without hurting life, yet none are fitted for its support excepting the Air, or Atmosphere, with which the Creator has so bountifully enfolded the globe, and it is essentially a Mixture of Nitrogen and Oxygen, in the annexed proportions per cent.

By Measure.		By Weight.	
Nitrogen . .	79	Nitrogen . . .	77
Oxygen . .	21	Oxygen	23
	100		100

One hundred pints of air, and one hundred pounds of air, therefore, contain respectively twenty-one pints and twenty-three pounds of oxygen. The energetic character of the Oxygen is modified or diluted by the larger portion of the passive Nitrogen; for if this latter element were not present in the air, candles and fires would burn as fiercely and rapidly as the paper allumette in the last experiment, every steady combustion would be a swift conflagration, and moreover animal respiration would become so hurried, that death

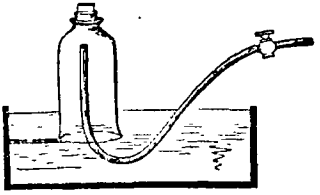
would ensue from intense morbid excitement of the nervous system.

A man in breathing consumes nearly six hundred and forty pints of oxygen gas from the atmosphere during twelve hours; making fourteen thousand four hundred inspirations, and during the short time which elapses between an inspiration and an expiration the air is totally changed in its character; by some mysterious power the oxygen is abstracted and united with the carbon, which is one of the elements of the animal body.

Carbonic acid gas is as perfectly formed as in experiments already mentioned, and this is expelled from the lungs with the unaltered Nitrogen, quite unfit for the support of life or flame. Thus, if air be blown from the mouth through a reed or tube into a glass filled with lime-water, carbonic acid will be detected by the formation of carbonate of lime, as in the experiment at page 23, from the combustion of the candle.

That air expelled from the lungs is incapable of supporting flame, may

be proved by the following simple experiment, the form of which is here shown.



The engraving represents a stoppered bell-glass full of air, standing upon the shelf in the trough of water, so that a bent metal pipe half an inch in the bore, may have one end thrust up near the top of the glass, whilst the other, provided with a stop-cock, remains outside; let the lips be applied to this end of the tube, so as to draw the air from the glass into the lungs, and then to force it back again, and so on for two or three times; close the stop-cock the last time that the air is forced into the glass, and then withdraw the tube whilst the glass remains upon the shelf.

Proceed with the glass exactly as directed at page 72, for examining the properties of nitrogen; namely, sink the glass, so that the level of the water in it coincides with that in

the trough; then remove the stopper, and insert a lighted taper, which will not burn, because the Carbonic acid produced, and the Nitrogen liberated during the act of breathing, are unfit for the support of flame.

A constant supply of fresh air is as absolutely essential for the maintenance of life as for the support of combustion; and persons soon become painfully sensible of this fact in small or crowded rooms, by the giddiness, fainting, and difficulty of breathing that they experience.

A frightful example of the want of fresh air is presented in the account of the horrid sufferings of one hundred and forty-six unfortunate Englishmen, who were confined, during a sultry night, in the Black Hole of Calcutta; only twenty-three of them survived until morning.

Consider the myriads of animated beings who are consuming the vital principle of Air; add to them its vast consumption by candles, lamps, gas-lights, fires, &c., and it forms a subject well calculated to excite surprise, that the whole atmosphere does not become so altered and contaminated by the joint operations of

respiration and combustion, as to be unfitted for the discharge of its important functions to both phenomena; yet, from the earliest period of analytical chemistry up to the present hour, not the slightest variation in the relative proportions of the elements of the Air has been detected.

Some wonderful power for the renovation of the Air is undoubtedly provided by the Creator for the welfare of His creatures, because throughout the works of God, all is beauty, harmony, and order; but even supposing that no renovation take place, the incomprehensibly enormous weight and volume of Air around the Earth should be remembered, and then the respiration of the millions of animated beings, the combustion of tens of thousands of fires, though apparently fertile sources of matters hurtful to vitality, all shrink into nothingness; they may be compared to a few drops of active poison mingled in the wide waters of the ocean, and so diffused as to be harmless, and to escape detection by the most refined chemical tests.

Again, the Air is not a stagnant or immoveable volume of gaseous elements, but is con-

stantly in a state of change and agitation, induced by the agency of solar heat; hurtful matters are wafted away and rendered powerless by the winds, storms, and tempests that arise; and although their immediate consequences are frequently deplored, yet they are wisely provided by the Creator for the ultimate good of mankind.

Having proceeded thus far in the present inquiry, the power of Oxygen in supporting the combustion of sulphur and phosphorus may be next examined, as such experiments will explain the meaning of the name by which this remarkable gas is denoted.

The pale blue flame with which sulphur burns, is well known; but if a piece of it be heated and kindled in a small copper spoon attached to the end of a wire, and then plunged into oxygen gas, the flame becomes enlarged, and of a beautiful purple hue.

The sulphur exerts its affinity for the oxygen, producing a vapourous compound called Sulphurous acid, which, if there be a little water poured into the bottle, is soon absorbed, and it will redden a bit

of lilac-coloured silk, or a bit of blue litmus paper; the latter is preferred by the Chemist as a simple test of acids; vinegar or lemon-juice will redden such paper.

Let a piece of phosphorus, the size of a pepper-corn, be placed in another small copper spoon, kindled, and plunged into oxygen gas; it will burn with a golden splendour so intense, that the eye can hardly endure the effulgence; the result is a white fume called Phosphoric acid, which water will dissolve, and then it will redden the blue litmus test-paper.

The same acid was produced slowly, in the experiment for the evolution of nitrogen; but more rapidly in the present case, because the oxygen is in its pure state; the intense light is referrible to the enormous quantity of solid yet finely-divided phosphoric acid, which constantly showers through the flame, and becomes ignited, though not burned.

Sulphur burned in oxygen does not evolve much light, because the product of its combustion, the sulphurous acid, is a vapour incapable of ignition or combustion.

Many substances produce Acids by uniting

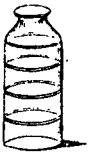
with oxygen, the result was soon found to be so general, that Chemists hastily concluded the element to be the Universal acidifying principle, and therefore called it Oxygen, a term derived from the Greek ὀξὺς, acid, and γεννάω, to generate; this name it retains, and most probably it will retain, though far from being correct, because the element is equally active in generating what are called Alkalies, to be mentioned hereafter; and compounds, which are neither acids nor alkalies, as the Oxides of lead and mercury already mentioned; they are neutral substances, and will not affect the test-paper.

Oxygen was likewise called the Universal supporter of combustion, from its general energy during the phenomenon, a term quite as incorrect as the other; for although its presence is indispensable for the support of common combustion, such as that of coals, wood, candles, and coal gas, there are many substances which will burn in its absence; thus phosphorus, antimony, iron, and potassium, will burn splendidly in the element Chlorine, in which no oxygen can be proved to exist.

No element is more universally diffused

throughout Nature than Oxygen, though it has never been discovered unmixed or uncombined with other elements; it exists in Air, as already shown; in water, as remains to be shown; and forms a large proportion of the earthy and mineral treasures of the globe, and of nearly every variety of animal and vegetable productions; from all which sources it can be elicited by the skill of the Chemist.

In the foregoing experiments, having analysed the Air, it remains to be proved that Nitrogen and Oxygen gases, when placed together in due proportions, will re-produce Air; this operation is called Synthesis, from the Greek *σὺν*, together, and *τίθημι*, to place, a term signifying the putting together; that of Analysis denoting the pulling asunder.



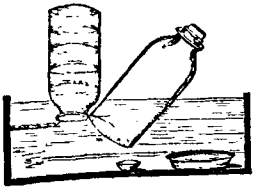
In order to perform the synthetical experiment, the following arrangements are requisite: a quart glass bottle, having a wide mouth and ground stopper, must be marked into five equal parts, by pasting four narrow bands of paper around it, as here shown.

Nitrogen sufficient to fill four of these parts,

and Oxygen sufficient to fill one part, must be prepared as directed at page 71 and page 77; all the fume of the phosphoric acid being allowed to vanish from the nitrogen.

The quart glass bottle, as it stands upon the table, is to be filled with water, and the stopper inserted; it must then be inverted, and its neck plunged beneath the water in the trough; the stopper is to be withdrawn whilst in this position, and the bottle, still full of water, carefully moved upon the shelf.

The plate containing the bell glass of nitrogen must be removed into the trough, and both plate and saucer sunk, as directed at page 72; and then, by sliding the mouth of the bottle rather more than half way off the shelf, the mouth of the bell glass is to be brought close against it, and slightly inclined, as here shown.



Allow Nitrogen from the bell-glass to bub-

ble through the water, as in the experiment with the air of the wine-glass at page 62, which is done by depressing the top of the bell-glass with one hand, whilst the other holds the bottle; the nitrogen will rise into it; allow it to do so until four parts of the bottle are filled, then slide it quite on the shelf; let the bell-glass be raised upright, but still with its mouth under water; and whilst in this position the plate can be again placed beneath it, and both lifted from the trough, provided there remain any nitrogen worth saving; if not, the bell-glass may be unstoppered, and lifted out, without any such precaution.

The operation now described is one of the many methods by which gases may be transferred from one vessel to another. The remaining division of the marked bottle has now to be filled with Oxygen from one of the stoppered bottles; and this can be done, by plunging the neck of the bottle of oxygen beneath the surface of the water in the trough; then withdrawing the stopper, then sliding the mouth of the marked bottle from the shelf, and bringing that of the other into the same position as last described for the bell-glass,

when oxygen will bubble up, and fill the marked space. The stopper of the marked bottle must now be inserted under water, and then it can be lifted from the trough, and placed in its usual position upon the table.

If any oxygen remain in the other bottle, it may be preserved by stoppering under water.

The operation is more easily performed than described; and a very little practice beforehand in transferring air from one bottle or jar to another will ensure success.

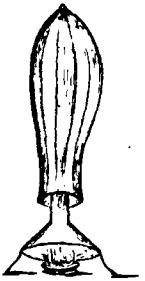
The marked bottle contains a Mixture of Nitrogen and Oxygen, in nearly the same proportions by measure as they exist in Air, namely, Four parts of the former, and One part of the latter; its power of supporting combustion may be examined; and having lighted a small wax taper attached to the end of a wire, the stopper can be removed, and the taper introduced; its flame will be neither extinguished nor increased, but it will burn with precisely the same quiet brilliancy as in the surrounding Air.

Having thus examined the essential chemical Elements of Air, some interesting phenomena dependant upon the combined effects of

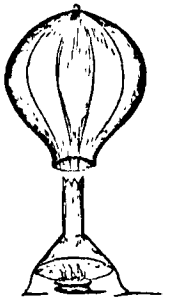
its expansion by heat and change by actual flame may be next introduced for consideration.

Air, Gases, and Vapours, when heated, expand in bulk, and diminish in weight; therefore, if unconfined, they have a tendency to ascend through the colder and heavier surrounding atmosphere; no better illustration of this fact can be presented than the Fire-balloon, its ascent depending upon the levity of heated air, and the products of the combustion by which it is heated and partially decomposed.

The Fire-balloon is a large globe of thin paper, having an aperture through which it may be inflated; in the accompanying figure the balloon is represented in a flaccid state, with its aperture held over a tin chimney, four inches diameter, two feet high, proceeding from a low funnel one foot diameter, supported on a tripod two inches high, and covering a tin plate, holding a flame burning from a sponge soaked in spirits of wine.



The products of the combustion of spirits of wine, namely, carbonic acid and watery vapour, both heated, together with a quantity of air heated and partially decomposed by rushing beneath the funnel to the flame, ascend into the balloon, which gradually distends until quite full; and then, if loosed from the hand, it mounts rapidly to a considerable height in the surrounding atmosphere; but as the contents cool, the balloon loses its ascensional force, and falls slowly towards the ground.



The first ascent of an experimenter into the atmosphere, was by means of an enormous Fire-balloon; and in order that it might continue buoyant, a grate was suspended in the centre of the aperture, filled with burning straw; this the adventurer replenished, or allowed to decay, from time to time, according as he desired to ascend or descend; several fatal accidents subsequently happened in consequence of the fire communicating with the paper of the balloon; this dangerous invention

is superseded by the Gas-balloon, which will be described hereafter.

Smoke from a chimney ascends into the air, for the very same reason as the Fire-balloon; and as all the comforts of an English fire-side depend upon the free and perfect egress of smoke from the burning fuel, a few observations concerning the matter may be here introduced.

When fuel is kindled in a common grate, it requires a plentiful supply of air, in order that it may burn freely; therefore, bars are placed below, as well as in front of the fire-grate, that air may have access to all parts of the fuel; and if the smoke and vapour resulting from the combustion ascend swiftly into the chimney, and from thence into the open air, it is commonly said to draw well.

Most persons attribute to the chimney some inherent or specific action, by which it draws smoke and vapour from the fire; but this is not the case, it being merely a pipe or outlet for the products of combustion; and these being heated, and lighter than air, ascend through it as the readiest means of escape into the external atmosphere.

The following is the whole theory of the

matter; the fuel is kindled, or, in other words, rapid chemical affinity is induced between its inflammable elements and the oxygen of the air in the apartment; the products of the combustion are nearly similar to those of the candle flame, formerly mentioned; therefore a portion of air is deprived of oxygen, the nitrogen heated, as well as the surrounding air; both are thus rendered lighter than the great bulk of colder air of the apartment, and therefore ascend the chimney; air from the apartment rushes forward to supply the fuel, so that the flame of the fire is constantly drawing upon the air of the apartment for support, and as in the case of the candle flame at page 25, the air which has thus yielded oxygen, and become heated, and formed new heated products, must have free escape, for if it be retarded as in badly-constructed chimneys, then it rolls back with the smoke in sooty volumes and fills the apartment.

Suppose the chimney to be perfectly constructed, it is absolutely essential that as much air should in some way enter the apartment, as the fuel consumes or causes to ascend in a heated state, and the endeavour of the air in the external

hall or passage to gain entrance and rush towards the fire, is announced by a whistling sound through the keyholes and crevices of the doors and windows; the chief entrance of the air to the apartment is through the space between the door and the carpet; this causes what is commonly called a draught, the danger of which is proverbial; it is a current of air which rapidly deprives the animal frame of heat, and produces the disagreeable and often fatal effect popularly called a cold.

If all crevices be stopped so as to prevent a draught, then the chimney refuses its office, the smoke descends into the apartment, and in many houses a window or door must be kept partly or even quite open, to admit the required supply of air, or otherwise the inmates of the apartment could not endure to sit there for the smoke; but this is only remedying one evil by the introduction of another, for it is by no means agreeable to remain in such a thorough draught.

Nothing can be more difficult than to admit a proper supply of air to the fire without causing inconvenience to the inmates of the apartment; some admirable contrivances

have been successfully adopted, but they are too complicated for description in this inquiry.

In order to warm an apartment comfortably by a common fire, the grate should be placed as near the hearth as possible; it should be wide and shallow, so that the heat may be thrown directly upon the floor; this imparts warmth to the air which sweeps over it surface; this warmed air ascends, colder air descends, in its turn becomes warmed, and thus currents are established which soon bring the temperature of the apartment to a proper degree.

In the ordinary method of warming apartments by open fires, even when the fire-places are most judiciously constructed, much heated air is lost by passing up the chimney; therefore to economize fuel, more particularly when very large apartments are to be warmed, the coal is burned in close stoves; the well-known German stove is an instance.

The advantages of this invention consist in the very small quantity of fuel which will maintain a very strong fire; the whole mass of the iron stove becomes heated to a considerable degree, and as it is usually placed in the

middle of the apartment, with its iron chimney or flue partly perpendicular and partly horizontal, the whole surface throws off heat very powerfully, and the air rushing forward to support the fire, impinging upon the heated surface becomes warmed instantly; it ascends, colder air descends, becomes warmed and ascends; and thus currents are more rapidly established, and the apartment more effectually warmed than by the combustion of the same weight of fuel in the ordinary fire-grate.

Very little heat is lost if the flue be tolerably long, and very little smoke passes out at its extremity, because the draught of air through the door of the stove is rapid and powerful, so that all the inflammable matter of the coal is consumed, (like that of the oil in the Argand lamp at page 36,) which is never the case in a common grate, and hence the necessity of employing a wretched climbing-boy to cleanse away the unburnt carbon or soot from the interior of a chimney.

It should be remembered that the German stove requires a supply of fresh air, as imperatively as an open fire-place, so that a draught is the inevitable consequence of its employ-

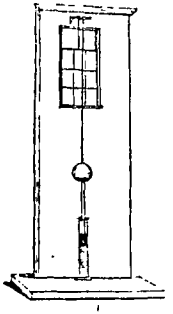
ment, unless it be supplied with air from a tube entering its lower door and opening into the external air; and if this be done, then there is very little chance of the air in the apartment being renewed; and unless the door of the apartment be opened frequently to admit fresh air, the whole atmosphere will become insufferably heated and unpleasant.

Care should always be taken that the iron-work of a stove never becomes red-hot, or it will gain the power of vitiating the air by combining with the oxygen, as the melted lead was stated to do at page 75; and though the apartment will be more powerfully heated by the red-hot iron, the air will be rendered unfit for the support of life.

In London, the air generally contains minute dust diffused throughout its mass, and this dust coming into contact with the red-hot iron of a stove, is burned, and produces a very oppressive odour.

The abstraction of oxygen from air, and the combustion of dust, by the action of the red-hot iron, are the principal causes by which apartments warmed by overheated stoves are rendered so proverbially unwholesome.

It is a very excellent plan to place a vessel of water on the top of the stove, that the water may evaporate and supply the air with moisture, and thus correct its oppressive dryness in some degree. Water is always present in the atmosphere in the state of vapour, and is indispensable for the support of life, as will be more particularly shown hereafter.



A very ingenious self-acting apparatus for opening or closing the window of an apartment, in proportion as the air becomes hot or cold, may be understood from the accompanying figure.

This represents the wall of an apartment having an opening near the ceiling, provided with a sliding window-sash, glazed in the ordinary manner; the upper part of this is attached to a rope, which passes over a pulley above the top of the opening, and then over another pulley at the same level, though supported at the end of a bracket, projecting one foot from the wall. The end of the rope proceeds downwards, and is attached to a ring on

the upper part of a thin iron bulb, twelve inches diameter, having an iron tube, one inch and a half diameter and three feet long, connected with it by close soldering, and open at the lower end, which dips into mercury, contained in a cylindrical iron vessel, rather larger than the tube, but of the same length.

A portion of mercury is also contained in the tube attached to the bulb, just sufficient to render its weight equal to that of the window sash, so that it may close the opening at the outset of the adjustment. The apparatus being thus arranged, if the air of the apartment become very hot, the air in the bulb will expand and force out a portion of mercury from its tube; thus rendered lighter, the bulb will ascend, in so doing, the window sash will descend, and allow the heated air of the apartment to escape through the opening; on the other hand, if the air of the apartment become cold, that in the bulb will likewise, and will contract, so that a portion of mercury will enter the tube; thus rendered heavier, the bulb will descend, and the window-sash ascend to close the opening.

The ventilation of apartments and buildings

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depends upon the escape of the air, which is heated and vitiated by respiration and combustion, and the entrance of fresh air to supply its place.

As heated air always ascends, it is the common practice to make an opening in, or near the ceiling for its escape, but a descending current of cold air is very likely to enter the apartment through the opening at the same time, unless the tube or flue connected with the opening be heated. This is effected in theatres by suspending the gas chandelier beneath a large metallic funnel, the tube of which passes into the open air.

When the gas is kindled, the funnel and tube become extremely hot, the vitiated air rises rapidly towards it and escapes, whilst cold air from without cannot enter, because the moment that it comes into contact with the heated tube it expands, becomes lighter, and ascends in company with that which is rushing from the body of the house.

Fresh air is allowed to enter through proper openings, situated near the floor of the house, and thus a large current sweeps through and proceeds upwards with the products of

respiration and combustion into the external air.

From the preceding statement it must be evident that the Air, or Atmosphere, is a boundless source of useful and interesting information, and did the limits of this general inquiry admit, much more might be said regarding the Mechanical and Chemical properties of this wonderful medium.

Sufficient has been said to prove that the Ancient Element Air, is a Mixture of the two Modern Elements, called Nitrogen and Oxygen. The latter will again claim attention as an Element of Earth, and Water.

CHAPTER III.

EARTH.

GREEK, ἄργιλος; LATIN, *terra*: FRENCH, *terre*.

By the generic term, The Earth, (γῆ or γαῖα,) is denoted the huge sphere eight thousand miles diameter, of which man is an inhabitant, bearing not so great a proportion to it, as the minutest atom of dust bears to the largest artificial globe.

Enveloped in its aerial mantle, the Earth performs an unerring revolution on its axis and in its orbit, around the million times more gigantic Sun, as a centre of attraction, and inexhaustible source of Heat and Light.

The air, the oceans, the mountains, valleys, and all their inhabitants, are held around the Earth, by its miraculous and unceasing power,

called Attraction of Gravitation, a power which the genius of the immortal Newton first unveiled.

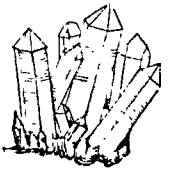
By the specific term Earth, (ἄργιλος or ὖλος,) the ancients denoted every variety of rock, stone, and soil, with which they were acquainted; the Alchemists extended the term to all substances which remained fixed, and unmetallic, during the most intense heat of their furnace fires.

The earliest scientific Chemists, who explored the ruins of Alchemy, discovered that the various stony, plastic, or pulverulent matters which form the mountains, valleys, and plains, resulted from the combination or intermixture of seven or eight distinct substances, infusible, and destitute of metallic lustre; such they called Earths, and regarded them as Elements, under which title they were received until thirty-five years since, when Davy decomposed them all, and proved each to contain a peculiar metal combined with oxygen.

Accordingly, the term Earth is almost banished from Chemistry, though it is occasionally used for convenience, or brevity of expression; the general characters of the substances which so long enjoyed the title are now

to be considered; their names are Silica, Alumina, Lime, Magnesia, Baryta, and Strontia; they are all Metallic oxides.

Silica, is an Oxide of Silicium, an inflammable metal, very difficult to obtain, and indeed all the Metals of this class of substances are beyond the reach of ordinary experimenters. The word Silica, is derived from the Latin *silex*, flint, which consists chiefly of oxide of silicium, but its purest form is the substance popularly called Crystal, or Rock-crystal, a mineral which occurs in a state of native beauty in many parts of the world, either as detached figures, or in groups, as here represented.



They are all regular six-sided prisms, having six-sided pointed summits; they are beautifully transparent, colourless, and hard enough to scratch glass.

This splendid mineral was well-known to the ancients, who imagined it to consist of

pure water, congealed into a harder, and colder form than common ice, and therefore incapable of thawing by the summer's sun, hence they named it Crystal, from the Greek κρύσταλλος, ice.

Chemists have applied the term Crystal, to every natural or artificial solid, of regular figure, however different it may be to that of Silica, and the Science which treats of these figures is called Crystallography, from the Greek κρύσταλλος, crystal, and γράφω, to describe.

The act of forming crystals is called Crystallization, which process will be exemplified a few pages hence.

Rock-crystal has many important uses, especially in the science of Optics; it is formed into spectacle or eye lenses, its clear, transparent, hard nature, fitting it admirably for such uses, as it does not become scratched when wiped or rubbed.

Pebbles, popularly so called, are slices of rock crystal, and are justly esteemed for spectacle lenses; but Silica is not always found free from colour, for those beautiful native gems, called Amethyst, Agate, Chalcedony, and Cor-

nelian, are varieties of it tinged of lovely hues by metallic matters.

Flint, and Sand, are impure varieties of the same abundantly diffused substance, but they are not regularly shaped or Crystalline, and therefore in common with all shapeless productions, are termed Amorphous, from the Greek ἀ, not, and μορφὴ, a form.

Silica cannot be artifically dissolved in water; it is therefore called insoluble, though its natural solution occurs in the waters of the boiling fountains, or Geyser fountains of Iceland.

By the action of strong solvents, very different from water, Silica may be dissolved, and though ordinary furnace fires have no power of melting it, yet by complicated methods of obtaining most intense heat, Silica has been melted and drawn into threads finer than human hair.

Silica when heated red-hot, with the Alkali called Potassa, forms a fluid, called Silicate of potassa, which when cold, is transparent, brittle, and popularly known as Glass, a term derived from the Latin *glacies*, ice, which it resembles in these characters.

The most important use of Sand is in the

production of Glass; a substance of inestimable value to man, for the promotion of scientific research, and domestic comfort; but the details concerning the art of glass-making are too voluminous for this general inquiry.

The proportions of the Elements of a Compound are always expressed by Weight, excepting they all happen to be aeriform or gaseous, and then they are expressed by Weight, and by measure, as in the case of Atmospheric air, at page 80. The combining weights of the elements of Silica, or Oxide of Silicium, are here annexed.

Oxygen	50
Silicium . . .	50
	100

From this statement, it appears, that one hundred parts of rock crystal contain fifty parts of the same element that exists in the Atmosphere, namely Oxygen.

Alumina, so called from the Latin *alumen*, clay, of which abundant substance it is the basis, is an Oxide of the metal Aluminum.

Alumina, occurs as a native crystalline mineral, called Adamantine spar, which is

second only to Diamond in hardness; but this is a very scarce form of the substance. Cornish, or porcelain clay, presents Alumina nearly pure, but amorphous, exceedingly soft, beautifully white, and emitting a faint odour when breathed upon.

Alumina, in this state is distinguished from all other substances, by forming a plastic mass with water, although insoluble; this property renders clay so invaluable for the manufacture of every kind of porcelain and earthenware.

Alumina is infusible by the greatest heat that can be artificially commanded, the only effect of the agent being to render it excessively hard, and incapable of becoming plastic with water.

Alumina, in its ordinary state of clay, when mingled with a large proportion of powdered flint, and beaten into a mass with water, is still highly plastic, and forms the material employed by the potter for the fabrication of useful or ornamental vessels; these, when heated red-hot, are deprived of the water which constituted their mould of form, and they become excessively compact and hard.

If broken, and pounded into the finest dust, this will not form a plastic mass with water, because the plasticity of clay depends upon water with which it is naturally combined, before other water is artificially added.

Perfectly dry Alumina, or Oxide of Aluminum consists of

	Parts.
Oxygen	46.7
Aluminum . . .	53.3
	100.0

Alumina, constitutes several beautiful gems, the principal of which are known as Sapphire, Ruby, and Emerald.

The Chemist forms many artificial compounds of Alumina; one of these popularly called Alum, is well-known, and it may be obtained in very beautiful crystals, by a simple process. Take two pounds of common Alum, dissolve it in two quarts of water boiling in a tin saucepan, set over an ordinary fire; let the solution continue boiling until a little of it, taken out in a tea-spoon, and set to cool near the open window, shows crystals upon the surface, or in the bowl of the spoon; they indicate that the

whole of the solution in the saucepan is ready to crystallize.

In other words, a hot saturated solution of Alum is thus obtained, which, as it cools, parts with a portion of alum in the form of crystals, for alum is more soluble in hot, than in cold water.

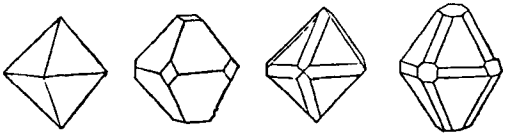
Let the whole of the solution be now poured into a tall earthenware jar, that will be quite filled with it, and let the jar be placed upon a shelf, or steady table, that it may not be disturbed.

Select a piece of coke, about the size of a small orange, bore a hole through this with an awl, so as to pass a string, by which the coke may be dipped into the solution of alum contained in the jar, the coke will float, but when it becomes fully soaked, it will sink, therefore the string should be left sufficiently slack to allow of its sinking to the middle of the solution.

In the course of a few hours, crystals of Alum will form, and adhere to the coke, and if the experiment be made in the evening, in the course of the next morning the coke will be found completely encrusted with beautiful

crystals of alum; these must be wiped dry with a cloth, and the specimen will retain its beauty for many months, if not kept in a very hot room.

The true form of a crystal of Alum is the regular Eight-sided solid called an Octoëdron, from the Greek ὄκτω, eight, and ἕδρα, side; it is shown in the first of the annexed figures. The octoëdron is liable to several modifications on its angles and edges; thus, in the second figure, the angles are wanting, in the third, the edges are wanting, and in the fourth, both angles and edges are wanting; or, in other words, the original octoëdron is said to be truncated, (from the Latin, *truncus*, cut short,) on its angles and edges.



A considerable quantity of solution will remain in the jar, and if this be poured away the bottom of the jar will be found encrusted with crystals; these may be removed and added to the solution, which, if again boiled and

allowed to cool, will deposit more crystals upon a piece of coke, placed in it as already described.

The object of placing the coke in the solution, is to afford the growing crystals a support for their attachment, or else the whole of them would encrust the bottom and sides of the jar.

A solid substance thus introduced into a solution which is brought to the proper point for crystallizing, is technically called a Nucleus, a Latin word signifying a *kernel*, for the crystals encrust or surround it, the same as the shell of a nut encloses its kernel.

The solution which remains after the deposition of crystals is called Mother-liquor, in consequence of having given birth to crystals.

Alum, or crystallized sulphate of alumina and potassa, consists of

	Parts.
Sulphuric acid . .	33·8
Alumina . . .	10·6
Potassa . . .	10·1
Water	45·5
	100·0

Lime is well known, and generally obtained from a variety of marble called Limestone, which is very abundant in many parts of England; and if it be heated red-hot in kilns, the lime remains as a white solid mass, popularly called Quick-lime, or Live-lime, in allusion to its active, strong, and caustic nature, as it corrodes and destroys animal and vegetable substances with great facility.

Lime has a very powerful affinity for water, which, when poured upon it, combines with the evolution of great heat; this operation is called slaking the lime, and is conducted on a large scale by builders before mixing the lime with sand for mortar, which is of inestimable value in architecture, where stone, marble, or brick-work require cementing together, as it sets or hardens into a very solid compact mass.

When Lime, or any other substance, combines with Water, the result is called an Hydrate, (the term being derived from the Greek ὕδωρ, water;) but it does not necessarily imply that an actual solution of the substance takes place, although such is frequently the case to a considerable extent.

Thus, if slaked lime be mixed with water into the consistence of cream, and allowed to remain at rest for some hours in a stoppered glass bottle, the greater part of the lime will subside or precipitate to the bottom, leaving a perfectly clear liquid, containing only a very little lime in actual solution, but tasting strongly acrid, and having the property of restoring the blue colour to litmus-paper, which has been reddened by an acid: it is one of the substances called Alkaline, and it combines with, or neutralizes acids.

The aqueous solution of lime obtained in the foregoing process is called Lime-water; it undergoes a curious change when poured into a shallow dish, and exposed for some hours to the air, it becomes covered with a white film, and loses its acrid taste and action upon the test-paper.

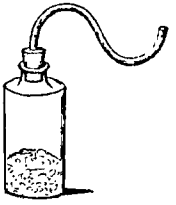
In many former experiments, Lime-water was employed as a test for carbonic acid; and the change just alluded to depends upon the formation of carbonate of lime, from a very minute quantity of Carbonic acid, which Air invariably contains, in addition to its larger essential elements, Nitrogen and Oxygen.

The fact is, that the lime contained in the lime-water, when exposed to air, reverts chemically to the same state as that in which it existed in the limestone previous to the action of heat, limestone being a natural compound of carbonic acid and lime, or carbonate of lime.

The affinity between these two substances being destroyed by fire or heat, the carbonic acid evaporates along with the smoke of the furnace, whilst the lime remains in a pure state, but ready to unite again with carbonic acid, whenever it may be presented; for this reason pure lime-water is used as a test of carbonic acid, be it produced by combustion, respiration, or any other means.

Limestone, or marble, which is chemically the same substance, may be also decomposed by a powerful agent called Muriatic acid, (from the Latin word *muria*, sea-salt, because extracted from sea-salt;) this acid will immediately liberate the gas in question, so that its properties can be examined with the greatest facility. The apparatus required is very simple: let a pint glass-bottle, with a narrow mouth, be provided with a cork through

which a bent pewter tube, half an inch diameter, passes tightly, as here shown.



In the bottle, place two ounces of small fragments of white marble; then quickly pour in sufficient muriatic acid to cover them; immediately insert the cork, with its tube, into the neck of the bottle: and then dip the end of the tube beneath the water in the trough; numerous bubbles will escape, which result from the strong effervescence that is taking place in the bottle: they are bubbles of carbonic acid gas, and may be collected in bottles filled with water, and inverted, exactly as described for oxygen, at page 77.

The theory of the action which produces the effervescence may be readily understood; Marble is a compound of carbonic acid and lime; they are united by a certain degree of affinity; but muriatic acid has a greater affinity for

lime than carbonic acid has, and therefore unites with it to form Muriate of lime, and expels the Carbonic acid in its pure gaseous state; this is a very instructive example of chemical affinity; and if sufficient muriatic acid be used, the whole of the marble will vanish, having yielded its lime to the muriatic acid, and its carbonic acid gas to the bottles in the trough.

The properties of the gas thus collected may be now examined; it is colourless and invisible, like Nitrogen, Oxygen, or Air; but a slip of pale blue litmus-paper put into it, which may be done as the bottle containing it stands on the table, is slightly reddened.

If Nitrogen or Oxygen be similarly tested, they exert no such action on the test-paper, provided they contain no acid derived from the solution of the fumes of phosphorus in the water of the trough, in which case the reddening will be permanent, because phosphoric acid is not a volatile acid, like the carbonic, which will escape if the paper reddened by it be exposed to the air, and the blue colour will re-appear.

Chemists have discovered that carbonic acid

is a compound, containing Oxygen fully saturated with Carbon, and therefore incapable of exerting affinity for any more; accordingly, if a lighted taper be plunged into a bottle-full of the gas, its flame is extinguished, as if dipped into water.

Carbonic acid gas is considerably heavier than air; and if, for the sake of example, a bottle be supposed capable of holding one ounce by weight of air, it would hold one ounce and a half of the gas, so that it is usual to call carbonic acid once and a half as heavy as air; and this difference in weight, though trifling, is amply sufficient to cause the gas to fall through air, as easily as water is poured through air from one vessel to another. The experiment is very remarkable, and may be performed in the following manner.

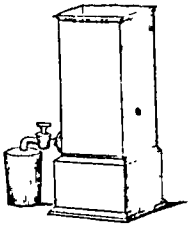
Take a pint wide-mouthed glass-bottle, empty, in ordinary language, but actually full of air; place it upon the table, remove the stopper, and then plunge a small burning taper into the bottle for a moment, to prove by the combustion that air is present; take a similar sized bottle of carbonic acid gas, gently withdraw the stopper in an upright position, and

place its mouth close against that of the bottle containing air; make the same movement of the hand, holding the bottle of gas, as if cautiously pouring out a liquid from the one bottle to the other, as shown in the annexed sketch.

Nothing will be seen to pass during this act, but that the gas has actually passed, will be evident directly that the lighted taper is introduced into the bottle which stands on the table, for the flame is extinguished.

Let it be re-kindled, and introduced into the bottle which originally contained carbonic acid, but which now contains air, and the flame will burn with its usual brilliancy; the contents of the bottle on the table may either be poured back to the other, or tested by the addition of lime-water, when carbonate of lime will appear.

Carbonic acid may be drawn exactly like water from a cistern, by adopting the arrangement here represented.



It consists of a wooden tube, five inches square, and eighteen inches high, open at each end, the lower being united to a hollow pedestal, six inches square and five inches high, closed by the wooden plinth upon which it stands; a small tap, similar to one employed for drawing water from a cask, is fixed into the wooden tube just above the pedestal, and closed; into this pedestal must be let down by a string, a pint wide-mouthed bottle, containing fragments of marble and muriatic acid, in the proportions already directed at page 118.

Carbonic acid is thus abundantly evolved; in the course of a few minutes it will fill the wooden tube, as may be proved by the intro-

duction of a lighted taper; its flame will be extinguished.

Now let a small tumbler be held beneath the tap, and by turning its handle so as to open it, the gas may be drawn off into the tumbler, and tested by the flame of the taper; it may then be inverted, and emptied like a tumbler of water; again filled, and so on until all the gas is drawn off. Or the tumbler may be suspended by strings, and let down into the reservoir of gas, like a bucket into a well; then drawn up full of gas, and tested by the flame of the taper; lastly, the gas may be poured out and the tumbler let down again for another supply.

Knowledge of the last-mentioned fact is of great practical utility, for carbonic acid gas is frequently evolved by natural operations in deep mines and wells; in such situations it remains on account of its weight, without mingling with the air above; the miners and well-diggers called it Choke-damp, on account of the instant suffocation which it produces; and, being invisible, they cannot discover the exact situation of its lurking-place, unless they

let down a lighted candle, which is extinguished directly upon touching it, thus warning them of the danger of descending; and careful workmen never attempt, to explore situations in which Choke-damp is suspected, without previously sending down the simple test of a lighted candle.

Choke-damp may be drawn from the shafts of mines or wells, by large buckets, and emptied away on the ground at some considerable distance from their openings; it soon becomes lost and diffused in the surrounding air; and the progress made in this, to an ordinary observer, apparently futile labour, may be judged of by letting down a lighted candle from time to time, and when its flame burns freely, the workmen may descend without danger; but whilst they are engaged in their occupation below, should the flame grow dim, it is prudent for them to ascend.

The Grotto del Cano derives all its celebrity from containing carbonic acid gas, evolved by the neighbouring volcanic soil; and on account of the floor being considerably lower than the threshold of the entrance, the gas remains

there as a distinct stratum; or if more be generated than can be there contained, the excess flows over the threshold, and does not rise to fill the upper part of the grotto, which therefore contains air.

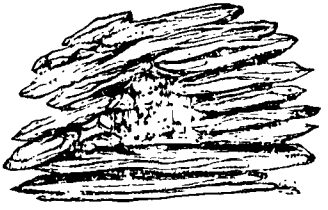
Accordingly, if a dog be thrown upon the floor he is suffocated, by being totally plunged into carbonic acid gas, whilst a man may enter with impunity, if he stand upright, because, on account of his height, his head is far above the noxious exhalation, and he breathes the air near the roof of the grotto.

It may also be remarked that the flame of a candle would cease in the one situation, but continue in the other.

History records that two slaves, whom Tiberius caused to descend into the Grotto del Cano, were immediately suffocated, and two criminals that Peter de Toledo caused to be closely imprisoned there, suffered the same fate, because the whole grotto became filled with carbonic acid gas when its aperture was closed.

The famed lake of Averno formerly exhaled so large a quantity of carbonic acid gas that birds could not fly over it with impunity.

A very pretty contrivance for explaining the theory of the Grotto del Cano, is shown in the annexed sketch.



It is a model constructed of wood; into its cavity, which represents that of the grotto, a small cup, containing marble and muriatic acid is placed, which will soon fill the lower part with carbonic acid gas; a lighted taper induced into it will be extinguished; if it be withdrawn, rekindled, and introduced into the upper part, containing air, it will burn with freedom.

The foregoing experiments prove carbonic acid gas to be heavier than air, and it always is so, provided it be no warmer than air; but if it be heated, then it expands, becomes lighter and ascends through air, as mentioned at page 93, or as may be shown in a more de-

cided manner, by holding a moderately heated iron-ball, or poker, in a bottle full of the gas, as here represented.

The gas will immediately expand by the heat and ascend, whilst the air will descend and fill the bottle, as the introduction of a lighted taper will show when the ball is removed.

The carbonic acid and nitrogen gas, which are simultaneously expelled from the lungs during respiration, are considerably warmer than the surrounding fresh air; therefore they swiftly ascend and are diffused, whilst it descends for the due support of life.

If the solution of Muriate of lime, formed in the experiments for the evolution of carbonic acid, be poured from any remaining marble into a vial and shaken with its own bulk of a strong solution of Pearlash, which is a carbonate of the Alkali potassa, the two transparent liquids produce a hard white solid, in consequence of the Muriatic acid suddenly combining with the Potassa, and forming Muriate of potassa, and the Carbonic acid with the Lime forming Carbonate of lime; the very same substance, che-

mically speaking, is thus produced with which the present inquiry commenced.

The interchange of components that ensues is very curious, and Chemists are unable to say why muriatic acid in its pure state should so readily expel carbonic acid from carbonate of lime; and when combined with lime, that carbonic acid combined with potassa, should in turn expel it, so as to reproduce white solid carbonate of lime; but the experiment, in common with many others, proves the impossibility of anticipating the results of chemical affinity.

Carbonic acid combines with many substances besides lime, producing Carbonate, some are insoluble in water, others soluble; but they all yield up carbonic acid by the action of other acids, of which a familiar example is presented in Soda-water powders, which consist of Tartaric acid and Carbonate of soda; upon the addition of water, solution takes place; the former expels carbonic acid from the latter, which effervescing forms the sparkling and refreshing draught so well-known, for although carbonic acid when inhaled, is a poison, yet when drank, it is harmless.

Soda-water, which is sold in glass-bottles, consists of water, containing a small quantity of carbonate of soda, and a large quantity of carbonic acid gas, which has been forced into it by powerful machinery, and the effervescence which ensues when the cork is drawn depends upon the sudden escape of the imprisoned gas.

Carbonic acid, produced or evolved by any process, invariably consists of

	Parts.
Carbon	28·6
Oxygen	71·4
	100·0

Carbonic acid may be produced immediately by burning charcoal in oxygen.

Let a piece of charcoal, prepared from the bark of a tree, be secured by a wire in a small ladle, kindle it in the flame of a spirit-lamp, and plunge it into a bottle full of oxygen, as at page 85, brilliant scintillations will ensue, and when they cease, lime-water poured into the bottle will produce carbonate of lime.

Whenever charcoal is burned, either in pure oxygen or common air, carbonic acid gas results; hence the danger of warming apartments with burning charcoal, for the air becomes so contaminated with the noxious vapour, as to produce giddiness, fainting, and even suffocation of those persons who may be present.

Charcoal, when used as a fuel, should be consumed in a fire-place, as ordinary coal, and then the products of its combustion escape into the external air. The small quantity of burning charcoal in the chafing-dish or crucible furnace at page 76, will not seriously vitiate the air of a large and well-ventilated apartment, but many persons are so sensitive that it might annoy them; and if such be the case, a large spirit lamp flame may be substituted for the burning charcoal.

Lime is a Compound of the Elements Oxygen and Calcium, a metal so called from the Latin *calx*, lime; it is very difficult to obtain, but is described as being brilliant like silver, and highly combustible, producing lime by uniting with the oxygen of the air; therefore Lime,

chemically speaking, is an Oxide of calcium, and it consists of

	Parts.
Oxygen	28·6
Calcium	71·4
	100·0

Carbonate of Lime consists of the above compound substances, Carbonic acid and Lime, in the following proportions:

	Parts.
Carbonic acid . . .	44
Lime	56
	100

These are called its Proximate elements, because it results directly from their union, and into them it can be directly resolved; they in turn may be resolved into Carbon, Oxygen, and Calcium, in the annexed proportions:

	Parts.	
Carbon	12·58	44
Oxygen	31·42	
Calcium	39·98	56
Oxygen	16·02	
	100·0	

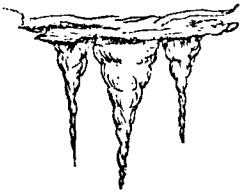
These constituents cannot be further analysed, and are therefore called the Ultimate elements of the carbonate of lime, and hold their rank with others of similar refractory characters, a list of which has been given at page 8.

Carbonate of Lime is the most abundant natural source of Lime; it exists in every variety of marble, limestone, calcareous spar, stalactite, chalk, and shell.

The white marble so highly prized by sculptors is called Primitive marble, as it is supposed to have been one of the rocks of the World before the Deluge; it never contains organic remains, such as bones or shells, which abound in limestone and chalk; these are called Secondary marbles, and are supposed to have been formed from primitive rocks, ruined or broken by the waters of the Deluge, and thus to have entangled the remains of organized beings.

Black marble, called by mineralogists Lucullite, from the admiration bestowed upon it by Lucullus, derives its blackness from the enormous quantity of organic remains that it contains.

Stalactite, so called from the Greek σταλαζω, I drop, is another variety of carbonate of lime, formed by the agency of water, which, when containing carbonic acid, is capable of dissolving carbonate of lime; this water, permeating through the roofs of caverns in limestone rocks, hangs there in drops; as the carbonic acid escapes, a little carbonate of lime deposits; drops succeed drops, until masses of carbonate of lime, resembling icicles, are formed, which hang from the roofs in the most beautiful manner. The limestone caverns of Derbyshire present fine specimens of stalactites.



If a basket or a bundle of twigs be immersed in the waters of a spring, containing carbonate of lime in solution, they will become incrusted with it, and apparently changed into stone, or

petrified; the petrifying well at Matlock owes its celebrity to this cause.

The manner in which carbonate of lime is dissolved by carbonic acid gas, may be artificially shown in the following manner.

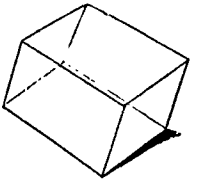
Let a tea-spoonful of lime-water be poured into a quart bottle filled with carbonic acid gas, carbonate of lime will be instantly formed.

Close the mouth of the bottle with a cork, and shake the bottle for a few minutes, the white carbonate of lime will vanish, because it is soluble in the large quantity of carbonic acid gas that is present; and the liquid in the bottle becomes pellucid; pour it into a wine-glass, and allow it to remain for some hours exposed to the air, the carbonic acid will escape, and the liquid will become white from the deposition of the carbonate of lime.

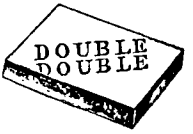
If the pellucid liquid be poured into a Florence flask, and gently heated over the flame of a lamp, the carbonic acid will escape more readily, and the precipitation of the carbonate of lime will be accelerated.

Carbonate of lime is abundantly found in a natural crystalline state, it is popularly called

Calcareous spar; and assumes several hundred different figures, all of which are derived from the obtuse Rhomboid here shown.

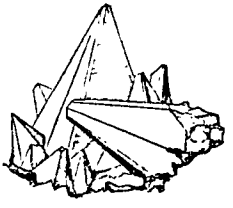


When carbonate of lime occurs in this form, perfectly transparent, it is called Iceland-spar, in allusion to its locality, or Double refracting spar, from the power which it has when placed upon an object, such as a printed word, of refracting or breaking the rays of light into two portions, so that a double object is presented to the eye, as thus

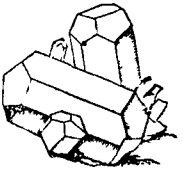


The following figure exhibits a variety of Carbonate of lime, which, from its supposed resemblance to the tooth of a dog, is popularly called Dog-tooth spar. It is a six-sided pyramid; sometimes two of these are joined base

to base, and form a twelve-sided figure, called a Dodecaëdron, from the Greek δώδεκα, twelve, and εδρα, side.



Another common form of Carbonate of Lime is the Six-sided prism, whose extremities are truncated or cut off in opposite directions; these crystals often present very beautiful groups, as here shown.



Any crystalline variety of carbonate of lime, if slightly struck by a hammer, will shatter or cleave into little rhomboidal fragments, and if these be further broken, they yield smaller fragments of the same shape; no other can be obtained from them, and therefore the rhom-

boid is said to be the Elementary or Primitive form of carbonate of lime.

By rude force, the rhombic fragments may be reduced to powder; but by gentle blows they will invariably cleave into others of a similar shape.

There are many natural compounds of lime, besides the carbonate; thus the compound of Sulphuric acid with lime, or Sulphate of lime, presents the beautiful substance called Alabaster; its name is derived from the Greek α, not, and λαβον, a handle, signifying difficult to hold, on account of its smooth slippery texture, and its employment by the ancients for forming boxes without handles, for containing ointments and perfumes.

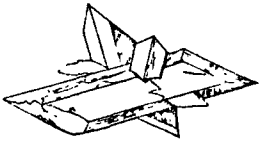
Alabaster is not found regularly crystalline, but in shapeless masses; it is of the purest white, and so soft as to admit of being easily carved into vases, and groups of figures of the most exquisite designs.

An impure variety of Alabaster, slightly tinged of a red colour, is called Plaster-stone, because when heated a quantity of water escapes from it, and a dry white powder remains, which, if mixed with water, forms a

plaster or cement, and soon hardens into a compact mass.

The preparation of plaster-stone is conducted upon a large scale in the neighbourhood of the capital of France, and hence the dry powder obtained the name by which it is popularly known as Plaster of Paris; it is much employed for forming busts, statues, ornamental mouldings, or other articles of decorative architecture.

Gypsum is a name by which Alabaster, Plaster-stone, or any other shapeless variety of Sulphate of lime, is frequently called; the name is derived from the Greek γη, earth, and εψεσν, to concoct, in allusion to its source; but there is a native crystalline variety of this substance, called Selenite, from the Greek σελην η, the moon, in allusion to the soft mild lustre of the mineral; its form is here shown.



This form is called the Rhomboidal prism, and occasionally the crystals are so beautifully

transparent, so easily cleaved into laminæ, and so large, as to admit of being used as a substitute for glass; but, when heated, water escapes, and they crumble into dry white powder, having all the properties of Plaster of Paris; this change will be adverted to in the ensuing chapter.

Dry sulphate of lime consists of,

	Parts.
Sulphuric acid . .	58·8
Lime	41·2
	100·0

Crystallized sulphate of lime consists of

	Parts.
Sulphate of lime . .	79
Water	21
	100

Lime combined with Phosphoric acid, chemically called Phosphate of lime, is occasionally found native, especially at Estremadura, and is popularly known as Phosphorite, from the property which it has of emitting a beautiful light, when thrown in coarse powder upon a plate of iron, heated to dull redness.

Phosphate of Lime, similar in composition to the native phosphorite, forms the hardening principle of the bones of man and animals; and these, when decomposed by refined chemical processes, yield the pure element Phosphorus, for experimental purposes.

Phosphate of Lime consists of

	Parts.
Phosphoric acid . .	46·2
Lime	53·8
	100·0

If bone consisted merely of phosphate of lime, it would be too brittle for the support of the animal body; accordingly, a cartilaginous substance accompanies it, which gives toughness and strength. If a bone be immersed in Muriatic Acid, the Phosphate of Lime will dissolve, and the cartilaginous substance will be left, perfectly soft and flexible; but if a bone be heated red-hot in the fire, the cartilaginous substance will be decomposed and burned, whilst the phosphate of lime, being unalterable by the heat, will remain as a white brittle solid.

Shells are divided into two classes, called

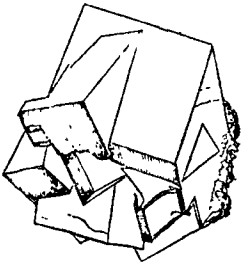
Porcellaneous, and Mother of Pearl shells; the former resembling porcelain, the latter mother of pearl; both contain, as a hardening principle, not the phosphate, but the carbonate of lime; indeed, porcellaneous shells consist of little else, and will entirely dissolve in muriatic acid; but mother of pearl shells contain a cartilaginous principle, closely resembling that of bone, which will remain in fibres or layers, after muriatic acid has removed the calcareous matter.

Fluor-spar, so called from the Latin word *fluo*, to flow or melt, as it is exceedingly fusible, is probably a compound of the elements Fluorine and Calcium, in the annexed proportions:

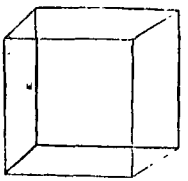
	Parts.
Fluorine	47·4
Calcium	52·6
	100·0

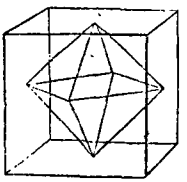
Its chemical name, therefore, is Fluoride of Calcium. It occurs in singular beauty in Derbyshire, sometimes regularly crystalline, at others in rounded masses; both varieties are tinged of the most lovely colours.

The crystalline form of Fluor-spar is the Cube, grouped as in this figure.



By gently striking the angles of the cube, they readily slide or cleave away, and a regular octohedron results, as here shown.





The Octohedron is therefore called the Primitive form of Fluor-spar.

The rounded masses, in which the mineral occurs, admit of being turned in a lathe into a variety of beautiful ornamental designs; or if one of the masses be sawn asunder, the section presents a series of concentric rings,

of various hues, as shown in the annexed sketch.

Magnesia, so called from being originally discovered in a province of that name in Asia Minor, was long regarded as an Earth; it, however, like lime, is an Oxide of a peculiar metal called Magnesium, which is very difficult to obtain, and very little known; whilst the contrary is the case with Magnesia: it consists of,

	Parts.
Oxygen	40·7
Magnesium . . .	59·3
	100·0

Plain magnesia is a Carbonate of magnesia; it consists of,

	Parts.
Carbonic acid . .	52.5
Magnesia	47·5
	100·0

It derives this popular name from being of a mild nature in comparison with the result which it yields when heated red-hot; during which operation, as in lime-burning, carbonic acid escapes, leaving pure magnesia, or Calcined magnesia: it is a fine, white, excessively light powder, and, like lime, it is alkaline, and will restore the blue colour of reddened litmus-paper, if placed upon it, moistened with water; but it is so very insoluble in water, that no solution can be obtained; a solid hydrate has been discovered, but it is an exceedingly rare mineral.

When substances are found in a natural state, they are said to be Native, in distinction to their artificial production; thus marble is native carbonate of lime, and the result of the experiments at pages 117 and 127, artificial carbonate of lime; a carbonate of magnesia is found native, combined with carbonate of lime, constituting a very important variety of compound marble, called Magnesian limestone; it is employed in architecture. York Minster may be cited as a splendid example of its application.

The stone used in the beautiful art of Litho-

graphy is also a variety of magnesian limestone; it has numerous other uses, in Chemistry and in Medicine; it is the great source of the Magnesia which forms a component of the crystalline substance popularly called Epsom salts, in consequence of being formerly exclusively obtained from the water of a spring near the town of Epsom, in Surrey, which for many years furnished the commercial demands; but this source has been abandoned, because Chemists have discovered, that by uniting magnesia with sulphuric acid a crystalline salt is produced, exactly resembling in all its characters that originally obtained from the above natural source; it is called Sulphate of Magnesia.

The formation of Sulphate of magnesia will present a good example of chemical affinity, and of attraction of crystallization; the operation may be conducted by diluting one fluid ounce of sulphuric acid with three fluid ounces of water, in an earthenware basin, and then gradually adding carbonate of magnesia, until effervescence ceases.

The theory of the action consists in the expulsion of carbonic acid gas by the sulphuric

acid uniting with the magnesia, and forming a sulphate of magnesia, which dissolves in the water, and the solution tastes very bitter and saline, exactly like Epsom salts.

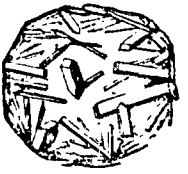
Crystals may be obtained by pouring the solution into a shallow saucer, and leaving it at rest in a warm room for a few days; these crystals may be collected by draining away the solution that covers them, and then their forms will be found to resemble those of the Epsom salts sold by druggists.

The principles of this miniature operation

carried out upon the large scale, with tons of the ingredients, enable the manufacturer to supply the enormous commercial demands for Sulphate of magnesia; the form of its crystal is a Four-sided prism, with opposed Dihedral terminations, so called from the Greek, δις, two, and εδρα, a side, as here shown.

Sulphate of magnesia is frequently obtained in crystals as large as the marginal figure; but those obtained by the process described are very small, yet, if examined with a magnifier, they

will be found to resemble it, and they are commonly grouped together, as shown in the accompanying figure.



The origin of the term Crystal has been explained at page 107; but here it may be stated, that the term Salt, is not confined to the common salt which is known in domestic use, for it is generally applied to a variety of compounds very different, and having no saline taste; thus, chemically speaking, Marble is a salt of lime, and Pearlash, a salt of potassa, the term being used for mere convenience; some salts are insoluble in water, others soluble; some are transparent and colourless, others opaque and coloured; some are poisonous, others are harmless.

Sulphate of magnesia is very soluble in water, but insoluble in spirits of wine; it is

well known that spirits of wine will mix readily with water; and these two facts may be taken advantage of for the performance of the following striking and instructive experiment.

Let an ounce by measure of the solution of sulphate of magnesia, drained from the crystals already mentioned, and which is saturated with the compound, be poured into a large wine-glass, which is to be filled with strong spirits of wine; then stir the two liquids together with a small rough stick, and in a few seconds a white mass appears, which sets or concretes so hard and solid to the glass and the stick, that the former may be lifted from the table by the latter.

The theory of the experiment is obvious; the spirits of wine exerts chemical affinity for the water in which the sulphate of magnesia is dissolved, and therefore combines with it; whilst the salt thus suddenly deprived of water, is liberated or precipitated in a solid form, and not regularly crystalline, for a reason which will be stated in the ensuing chapter.

Crystallized sulphate of magnesia consists of

	Parts.
Sulphuric acid . .	32·52
Magnesia . . .	16·26
Water	51·22
	100·00

The substance called Talc is a magnesian mineral; it is found in large blocks, which may be easily cleaved into thin leaves, so beautifully transparent, as to admit of being used as a substitute for glass in window frames; and in this application talc possesses an advantage over glass, inasmuch as it will not shatter by a blow.

Asbestos, so called from the Greek, *ἀ*, not, and *σβεσις*, to extinguish, is another magnesian mineral, and from the circumstance of being found in long soft flexible fibres, is popularly called mountain flax; these fibres admit of being spun into threads, which may be woven into a textile fabric by the loom; the ancients were well acquainted with this property of the mineral, and its indestructibility by fire, and therefore employed the lapideous fabric as an envelope for bodies which were

consumed on the funeral pyre, so that its incombustible nature might prevent human ashes from contamination with those of the fuel.

Asbestos was likewise employed by the ancients for making the wicks of their everlasting lamps; the moderns occasionally use it for a similar purpose, where a flame is required to continue burning for many days, without the wick requiring attention.

Another magnesian mineral, greenish, soft, and unctuous to the touch, is popularly called Soap-stone; the natives of China and Japan carve it into very grotesque figures and groups.

French chalk is a variety of soap-stone; its use for absorbing stains of grease is well known.

These are all the experiments that can be here adduced concerning Magnesia and its compounds; it now remains to say a few words regarding Baryta and Strontian, which are two curious substances, well known to Chemists, though by no means so plentiful as Lime and Magnesia.

In several counties of England, a heavy

mineral is found, which contains a peculiar substance, called Baryta, from the Greek *βαρύς, heavy*; it was formerly regarded as an Earth, but now as an Oxide of an inflammable metal, called Barium, which is very difficult to obtain.

Baryta consists of

	Parts.
Oxygen	10·4
Barium	89·6
	100·0

It is more alkaline, caustic, and poisonous than lime, and forms many natural and artificial compounds; it combines with a powerful acid, called Nitric acid, producing a crystalline salt, called Nitrate of Baryta, which consists of

	Parts.
Nitric acid	41·3
Baryta	58·7
	100·0

This salt can be procured at a very cheap rate, being largely consumed in the art of Pyrotechny for producing an emerald-green

flame; the other materials to be mentioned can also be obtained without difficulty; they are Sulphur, Chlorate of Potassa, and Sulphuret of Antimony; these must be separately weighed out in the following proportions for the Green fire composition.

	Parts.
Nitrate of Bartya . . .	77
Sulphur	14
Chlorate of Potassa . . .	5
Sulphuret of Antimony . .	4
	100

The scale pan must be carefully cleansed after the removal of each substance; they are then to be separately reduced to fine powder in a mortar, taking care to wash and dry it and the pestle between each operation; for if these cautions be not scrupulously attended to, a violent and dangerous explosion will inevitably happen. The separate powders are to be thrown upon a sheet of paper, and mingled together with a stiff card or feather.

A light green mixture is thus obtained, which, if placed in an earthen plate and kindled with a live coal, will burn, and shed a bril-

liant emerald-green light upon all surrounding objects.

Many years ago a mineral was discovered at Strontian in Scotland, and upon analysis it presented a distinct alkaline substance, which was deemed an Earth, and denoted by the name of Strontian, in remembrance of its native locality; it is an Oxide of an inflammable metal called Strontium, which is very difficult to obtain. The proportions of the two elements in Strontian are

	Parts.
Oxygen	15·33
Strontium . . .	84·67
	100·00

There are many natural and artificial compounds of this substance; its Nitrate consists of

	Parts.
Nitric acid	51
Strontian	49
	100

This salt can be purchased, it being prepared for the art of Pyrotechny, to produce a splendid rose-coloured light.

The ingredients required for the Red fire composition are as follows—

	Parts.
Nitrate of Strontian . .	65
Sulphur	21
Chlorate of Potassa . . .	8
Sulphuret of Antimony . .	6
	100

These materials must be weighed, powdered, and mingled with the same precautions as those already given; a dark-green mixture results, which when kindled sheds a splendid rose-coloured light upon surrounding objects. The chief use of the Nitrates of Baryta and Strontian is in Pyrotechny.

Such is a very general account of the substances which, in the infancy of Chemistry, were regarded as Earths; but which now rank as Metallic oxides; they enter into the composition of every variety of rock, mineral, and soil, and enclose ores and veins of ordinary metals.

CHAPTER IV.

WATER.

GREEK, ὕδωρ; LATIN, *aqua*; FRENCH, *eau*.

THE Ancient Element Water, is distributed throughout Nature, as lavishly as the Air; it is likewise as essential to the existence and welfare of the animated creation; but the total weight of its enormous quantity is beyond the reach of calculation.

Water gives diversity to the beautiful scenery of the globe, whether as the gushing fountain, the mountain torrent, the placid lake, or the gliding stream, which swelling to the rapid river is ultimately received in the parent bosom of the vast ocean.

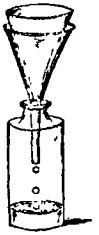
In the atmosphere water is always present in the state of invisible vapour, from whence in due season it descends in varied forms to

enrich and fertilize the earth, and maintain that order and harmony of Nature which is every where so conspicuous to the philosophic mind.

Water never occurs in a state of absolute purity; it invariably contains gaseous, earthy, or saline matters, derived from the air through which it falls, out of clouds, or from the strata of the earth, in which its springs originate, or throughout which they percolate.

Water often contain impurities mechanically diffused, and not dissolved, such as sand and clay; these may be immediately separated by the process of filtration, as in the common water-filter, which consists of a hollow porous stone, filled with water, and it slowly runs through perfectly pellucid, whilst the impurities remain behind.

Water may be filtered on a small scale, through porous white blotting paper, called by Chemists filtering paper, a square piece of it folded into four, and afterwards opened as a cone, may be placed in a glass funnel, the pipe of which is inserted into a bottle, as in the arrangement here represented.



Let turbid water be carefully poured into the paper cone or filter, the impurities will remain upon it, because they cannot pass through the fine pores of the paper as the water can; it is collected in the bottle.

If water contain impurities actually dissolved, then no filtration will separate them, and some chemical agent must be employed to purify the water effectually.

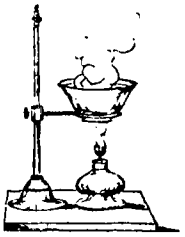
The following simple experiment will illustrate the difference between mere diffusion and actual solution; the one being a mechanical, and the other a chemical action.

A portion of fine white sand may be shaken with clear water, so as to render it turbid, and then poured upon a filter, the sand will remain behind, whilst the water passes as clear and tasteless as it was originally, because it cannot dissolve the sand; on the other hand, if a lump of common salt be shaken with clear water, it will vanish, or dissolve; if this solution be poured upon a filter, no salt will remain behind; and although the water passes clear, yet it tastes strongly saline, and neither filtration nor repose will separate the salt from

the water with which it is thus chemically combined.

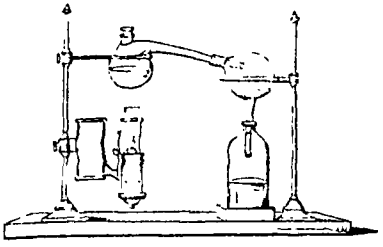
The chemical agency of heat will effect a separation between the water and the salt without difficulty; for if the solution be boiled in a basin set over a lamp, the water will evaporate as steam, and the salt remain in a solid form.

The apparatus is here represented.



If a cold glass tumbler be held over the basin during this evaporation, it will chill or condense the steam into drops of water, having no saline taste, because the salt is a fixed substance, and cannot rise at the same heat as the pure steam of the water. This simple fact enables the Chemist to purify water by the

process of distillation, (so called from the Latin *distillare*, to drop, or run down drop by drop,) the requisite apparatus for which, on a small scale is here shown.



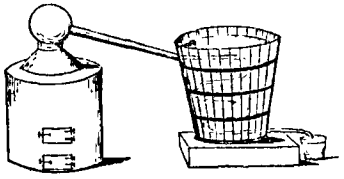
Two retort stands are provided, one for the support of a stoppered glass retort, the other for that of a glass receiver, into which the neck of the retort enters, whilst a tube from the receiver passes into a glass bottle beneath.

Water is poured into the retort until its bulb is one-half filled; the stopper is then inserted, and the flame of the lamp so adjusted as to warm the bulb of the retort gradually.

The water will ultimately boil rapidly, and the steam rising into the neck of the retort, and from thence into the cold receiver, will condense into drops of water which trickle down the tube to the bottle; the process must

be stopped when three parts of the water have thus distilled from the retort, lest the further application of heat cause the glass to crack; and if spring-water were originally employed, the residue in the retort will be found turbid from the fixed matter remaining.

This process of distillation is conducted on a large scale in metallic apparatus, to avoid the expense and risk, attendant upon glass vessels. The still and tub, as they are called, are here represented.



The still or retort consists of a copper boiler, set in a furnace, like a brewing copper, but when the water is introduced, it is closed with a globular-shaped vessel, having a tapered tube, resembling that of a retort; this is called the still-head; its small end is thrust into a pewter pipe, passing through the upper part of a tub, and coiled round several times, and

called in consequence a worm-pipe, the other end passes out through the bottom of the tub, which is filled with cold water, and called the still-tub.

A fire being kindled beneath the boiler of the still, the water soon boils, steam rises into the still-head and worm-pipe, where it is condensed by the surrounding cold water in the still-tub; the air that the water contains escapes through the open end of the worm-pipe, and is dissipated, whilst pure water trickles from it, and is received in a clean bucket or other suitable vessel; the earthy and saline matters remain in the boiler of the still, and by constructing the apparatus of sufficient magnitude, hundreds of gallons of distilled water may be obtained.

Distilled water, or pure water, which during the remainder of this chapter will be simply called Water, is a liquid perfectly colourless, transparent, inodorous, tasteless, and unchangeable, if kept in vessels upon which it can exert no chemical action, as in bottles of gold, silver, or platinum; in the heat of summer it is always liquid, but in the cold of winter changes into a solid called ice, and there is an im-

mutable degree of temperature at which this remarkable transition ensues, which can be proved by the Mercurial Thermometer: this is a very simple yet beautiful contrivance for denoting changes of natural and artificial temperature, by the expansion and contraction of fluid mercury; its most useful Chemical form may be understood from the figure now presented.

It is constructed of a fine glass tube, having a small bulb blown on one extremity, which contains mercury, as likewise does a certain portion of the tube or stem; this is attached by two metal loops to a strip of box-wood or ivory, called a scale, in consequence of being marked or graduated into many divisions or degrees, two of which, namely 32° and 212°, being distinguished by the words Freezing, and Boiling.

Let the bulb of the Thermometer be placed in a small cup full of water, which is afterwards introduced into a jar containing a mixture of equal parts of finely-powdered ice and common salt; this forms what is popularly called a Freezing mixture, on account of its common employment by the confectioner for

producing cream and water ices; it is also used by the Chemist for obtaining artificial cold, when necessary for experimental investigations.

The theory of the action of the ice and salt, is too abstruse for this discussion, therefore content with having a source of cold at command, let its action upon the water be proceeded with.

On the immersion of the thermometer into the water, the mercury in its stem may be at, or near 60 degrees, but as the water cools by the frigorific action of the surrounding mixture, the mercury gradually falls, until it becomes stationary at 32 degrees, and, then the water will become ice, or freeze, upon the slightest agitation ; the scale is therefore marked at this part as The Freezing Point, and although the experiment may be continually repeated, the water will freeze at no other degree.

Water, during transition from the liquid to the solid state, undergoes no chemical change, but merely a mechanical alteration or expansion of its bulk; if it be frozen in closed vessels which prevent this expansion from ensuing,

they are invariably broken by the force, as may be proved by filling an ounce vial with water, securing it with a cork closely strung and waxed over; and thus prepared, upon plunging it into the freezing mixture, the moment that the water freezes the vial bursts; and even bottles of wrought iron cannot resist this expansive force.

Having determined these facts regarding the freezing of water, the phenomena attendant upon its boiling may be examined.

Let the cup of frozen water of the last experiment be removed from the freezing mixture and placed near the fire, so as to thaw and liberate the thermometer; it cannot be safely used until the mercury again rises to 60 degrees, because a sudden transition from cold to heat, as from freezing to boiling water, would cause the glass bulb and tube to break.

Although the Air, or Atmosphere, envelopes the Earth to the extent already mentioned at page 58, and its total weight is so enormous, yet this is constantly undergoing local variations from many great natural causes: these variations in its weight are indicated by an instrument called The Barometer, the mercury

in which rises or falls according as the air is more or less heavy; hence the origin of the term Barometer, from the Greek, *βάρος*, weight, and *μέτρον*, a measure, denoting measurer of weight, whilst that of Thermometer, derived from *φέρμος*, heat, and *μέτρον*, a measure, in the same language, denoting measurer of heat.

The simplest form of Barometer is exhibited in the accompany figure.

The Barometer consists of a glass tube, one quarter of an inch internal diameter, and thirty-two inches long, closed at one end; this tube is filled with mercury, and then inverted with its open end into a small cistern of mercury: this being done, and the tube set upright, and fastened by loops to a wooden support or back, having a scale of inches at its upper part, the mercury is observed to fall for the space of two or three inches, so as to leave the upper end of the tube empty.

The mercury falls, because the surrounding atmosphere is unable to balance a greater height or column of the heavy metal; and if the mercury remaining in the tube could be removed, and accurately weighed, the result

would present the weight of a column of the atmosphere, of equal diameter with that of the bore of the tube.

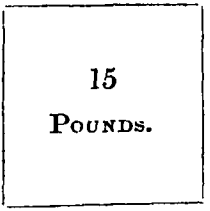
The mercurial column and the Aerial column mutually balance each other; if the latter fluctuate in weight, the former will in height, because there is no air in the tube above the mercury; it is void of air, or a vacuum; and if the instrument be slowly inclined into a horizontal position, the mercury will be found to fill it, which it could not do if air were present, any more than the water could enter the wine-glass at page 60, whilst full of air.

The tube of the Barometer is made thirty-two inches long, that there may be space for the ascent of the mercury, when urged upward by the external pressure of the air upon that in the cistern; if it were only thirty inches long, there would be no empty space in many states of the atmosphere, because it would be enabled to balance a column of mercury of that height; and the tube would remain full, until the weight of the atmosphere diminished, and then the mercury would fall, to a certain extent.

The enormous weight of the Atmosphere

mentioned at page 59, was detected by the Barometer; and the following account may explain the principles of the operation.

If a tube, exactly thirty inches long, and one inch square, closed at one end, be filled with mercury, the metal will weigh fifteen pounds; if the open end of the tube be inverted into a cistern of mercury, in certain states of the atmosphere, the tube will remain full: from this it is concluded, if a ponderous column of mercury can be thus supported by the atmosphere, that it must be pressing with a weight equal to Fifteen pounds upon every square inch of surface.



By calculating the number of square inches upon the surface of the entire globe, the total weight of the atmosphere is discovered to be represented by the enormous sum alluded to above.

This weight of air, though constant upon the whole, is liable to local variations, and these materially affect the boiling of water; and though it is true that on the scale of the thermometer 212 degrees announces the Boiling Point; yet, unlike that of 32 degrees, or the Freezing Point, it has reference to some Fixed or Standard weight of the air; or, in other words, 212 degrees of the Thermometer is the point at which water boils, if the mercury in the Barometer stand at the 30 inches marked upon its scale, at the level of the sea; then the Air is said to be at its mean or standard weight or pressure.

On a day when the mercury in the Barometer stands at, or near 30 inches, if a tin cupfull of water be set over the flame of a lamp, it will soon boil briskly; that is to say, the heat overcomes the pressure of the air which tends to preserve the water in a liquid state, and converts it, in defiance of this pressure, into vapour or steam, in which the bulb of the Thermometer may be held for a few seconds to warm, and then plunged into the boiling water; the mercury will rise rapidly in the stem, and at length become stationary very

near 212 degrees, or the Boiling Point; and there it will remain, however furiously the water may boil.

If the experiment be repeated on a day when the mercury in the Barometer stands at 28 inches, the Thermometer will not indicate 212, though the water apparently boils the same as before; but the mercury in the Thermometer stops at 210 degrees, or thereabout, because there is not so great a pressure of air upon the water as before, and the heat can more easily raise the water into steam; in fact, the boiling water is about two degrees colder than in the former experiment.

The mercury in the Barometer is sometimes considerably higher than 30 inches; and then, if the boiling of water be tried, the mercury in the Thermometer will pass beyond 212, because there is a greater pressure of air upon the surface of the water; and the heat having this pressure to contend against, renders the water hotter before it can rise into steam.

By means of the Barometer, Philosophers have discovered another remarkable fact concerning the atmosphere, namely, that it is not of an uniform density throughout its whole

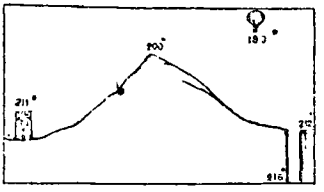
height at any time; but those portions of it which are directly incumbent upon the earth are thicker or heavier than others at more considerable altitudes; the same, to use a very homely simile, as the hay at the lower part of a stack is more compacted or pressed together than that at the upper part.

If the mercury in the Barometer stand at 30 inches when the instrument is on a plain at the level of the sea, it would fall considerably if taken up a mountain, because the air at such an elevation is rarer, thinner, or lighter, and therefore unable to support or balance so great a weight of mercury as the denser air on the plain beneath.

On the other hand, if the Barometer be taken to the bottom of a deep mine, the mercury would rise, because of the greater weight of a more lofty column of air exerted upon its surface.

The boiling point of water is found to be affected in a most remarkable manner, at various altitudes and depths from the plain surface of the earth; and for the sake of illustration let it be supposed, that at the foot of a mountain, water boils at 212 degrees; on a

high tower it might boil at 211 degrees; on the summit of the mountain at 200 degrees; in the car of a balloon at 190 degrees; and in a mine at 215 degrees: these variations in temperature being entirely dependent upon the difference in the weight and pressure of the air; thus, upon the summit of Mont Blanc water boils as low as 187 degrees; and at the bottom of a mine at Monkwearmouth it boils as high as 215 degrees. The accompanying outline may serve to illustrate this matter.



The following experiment presents an interesting example of diminished pressure facilitating the ebullition of water.

Let a strip of woollen cloth be bound two or three times around the neck of a Florence or foreign wine-flask, and tied securely, to form a handle, by which the flask may be held.

Provide a sound French cork, that accu-

rately fits the neck, and pour two fluid ounces of water into the flask; let it be placed, without the cork, upon the ring of a retort-stand set over the flame of a lamp, that it may heat gradually, until the water boils, and steam issues abundantly from the neck; hold this by the woollen cloth, suddenly remove the flask from the retort ring, and instantly insert the cork, the water will cease boiling; but if the flask be plunged into a jar of cold water, ebullition re-commences; the form of the arrangement is here shown.

The ebullition ceases if the flask be removed from the cold water, and held over the flame of the lamp; this appears a paradoxical experiment, but it admits of a satisfactory explanation.

In the first instance, by boiling the water

the air is entirely driven out of the flask by the steam taking its place; then, by removing the flask, and inserting the cork tightly into its neck, the external air is prevented from entering and mixing with the steam that is shut in; lastly, by plunging the flask into cold water, the steam is suddenly chilled or condensed, so that a void or vacuum is effected, and the water, thus relieved from all pressure, but still combined with heat, is enabled to boil at a temperature far below 212, perhaps as low as 180 degrees; whilst, on the other hand, if the flask be held over the flame of the lamp, steam is suddenly re-produced, and pressing upon the surface of the water, the same as air would do, prevents it from boiling at 212 degrees; the water would eventually boil at a higher temperature, but then the flask would be burst by the force of the steam.

High-pressure steam, popularly so called, is steam produced from water, heated in very strong metallic vessels, securely closed, so that it boils far above 212 degrees; and low-pressure steam is that evolved during the ordinary process of heating water in open vessels; both

are employed as motive powers in steam engines. If water be boiling at 212 degrees, and no fluctuation take place in the standard height of the Barometer, the boiling point may be greatly increased by the addition of substances soluble in water; thus, let a few lumps of common salt be thrown into the water, the mercury in the thermometer will rise considerably; and if as much be added as the water can dissolve, it will rise to 236 degrees, and there remain stationary; such temperature is therefore called the boiling point of a saturated solution of common salt; if this be artificially cooled, by a freezing mixture, it will not freeze until the mercury in the Thermometer sinks many degrees below 32, namely, to the 0^{o}, or zero of the scale.

From the foregoing experiments and observations, it becomes apparent that 212 is called the Boiling Point of water when perfectly pure, and heated in an open vessel, the air being at the standard pressure of 30 inches; the Freezing Point, or 32 degrees, is immutable under every change of pressure, and can only be affected by substances largely dissolved

in water; hence it is that the salt water of the ocean remains current, whilst the fresh water of the river is locked in ice.

The manner in which water becomes heated to its boiling point yet remains for explanation; this may appear a very simple matter of inquiry, but it will be found to involve several curious facts of Chemical philosophy. The facility with which water boils would naturally lead to the conclusion of its being a good conductor of heat; but the following experiments will prove the contrary.

Nearly fill a tall ale or champagne-glass with water; upon its surface pour a tea-spoonful of ether, which, being a very light fluid, will float, and being very inflammable, will burn, if touched with a slip of lighted paper; thus a flame is produced actually upon the surface of the water; the glass is here represented.

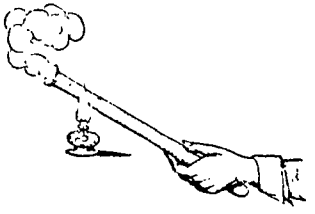
When the flame ceases, the water will be found very hot at the mere surface, but quite as cold as it originally was at a little distance

beneath; the Thermometer will indicate the exact temperature in both situations.

Pour water into a second ale-glass, until within half an inch of its rim; then take an iron ball, one inch diameter, attached to a stout iron wire, for the convenience of holding; let the ball be heated red-hot in the fire, and then held so as to touch the surface of the water in the glass; it will boil furiously, but the remainder beneath continues cold. The form of the experiment is represented in this figure.

Another experiment regarding the above fact may be made as follows: take a thin glass tube, twelve inches long, and three quarters of an inch diameter, closed at one end; pour in water until within two inches of the top, and then hold the tube by the closed end, so that the flame of a spirit-lamp may gently warm the tube near the surface of the water; in the course of a few minutes it will boil rapidly, but the hand will feel no heat, not even if it be moved within an inch or two of the

boiling hot water: the arrangement is shown in the figure.

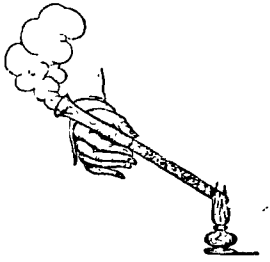


The experiment may be modified so as to present a more striking result, in the manner next to be described: let the water be poured away, the tube allowed to cool, then half filled with water, and plunged into a freezing mixture, until the water becomes ice; then remove the tube, wipe its exterior dry, and pour three inches depth of water upon the ice; let the tube be held in the hand, and heated, exactly as before; the water will boil rapidly at the surface, nay even within an inch of the ice, which will not thaw in the slightest degree.

The foregoing experiments prove that water cannot be a conductor of heat; if it were, then should it conduct heat to the bottom of the ale-glass, to the hand, or to the ice, because it matters not where a conductor, such

as a metal bar, is heated, either at its upper or lower end, or its side, the progress or conduction of heat throughout its mass is uniform, and can everywhere be detected by the hand.

Thaw the ice, by immersing the glass tube of the last experiment in a vessel full of hot water; empty its contents, and nearly fill it with water as at first; let it then be held at its upper part, and the lower heated by the flame of the lamp, as here represented.



In the course of a few minutes the tube will become so hot, that it cannot be endured by the hand, and therefore a strip of thick woollen cloth must be folded two or three times around the tube, that the fingers may grasp it safely; upon continuing the heat below, the water will ultimately boil rapidly.

In this experiment the water does not boil by conducting the heat, nor even by the glass tube conducting the heat; glass is a very imperfect conductor, and heat would travel from one of its extremities to the other with extreme slowness; a question then arises, regarding the cause of this remarkable and rapid distribution of heat throughout the water, if it be not by conduction; this can be explained in very simple terms.

Water, like air, when heated, changes its density, or becomes lighter by expanding; thus, when heated at the surface, it can no more descend to impart its heat to the cold water below, than a cork can descend to the bottom of water, in consequence of being so much lighter; the heated water actually floats upon the surface of the cold, and this can be rendered evident immediately, by holding a strip of blotting-paper, soaked with red ink, cautiously upon the surface of the water, heated in the ale-glass by the red-hot ball; the red ink will mingle with the heated water, and form a coloured stratum floating on the cold colourless portion beneath.

When water is heated at the bottom of the

tube, its lower portions become expanded, and rendered lighter, and therefore ascend through the colder portions above, exactly as the balloon ascended through the air; the colder portions falling down, become heated in their turn, and ascend; others descend; and thus the heat is diffused throughout the whole of the water, by the carrying power of ascending currents, until it is elevated to the Boiling Point: this distribution of heat is called Convection, from the Latin, *con*, together, and *veho*, to carry, and is obviously very different from Conduction, which is derived from the Latin, *con*, together, and *duco*, to lead.

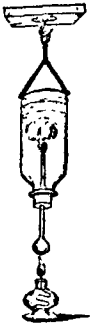
Ascending and descending, or convective currents, as the foregoing are called, ensue during the heating of all liquids except mercury, (it will heat from above, downwards, by pure conduction;) and although they are invisible, they can be detected in a very simple manner. A piece of white blotting paper, one quarter the size of this page, must be cut into shreds, the size of the annexed figure; : place these in a large Florence, or wine-flask, and nearly fill it with water; the paper shreds will sink to the bottom;

the flask may now be suspended by a wire-loop over the flame of a lamp, so as to heat gradually.

It will then be found that the currents of heated water, in ascending, carry up some of the paper shreds; (and the only reason why they are introduced is to detect the direction of the currents, the same as feathers thrown into the wind indicate its course;) but as they cool by imparting heat to the surrounding water, they lose buoyancy, (as the fire-balloon did,) and descend and carry down the shreds; they become heated, and again ascend; cooled, and again descend.

These actions will increase as the water becomes hotter; and when it fairly boils, the currents are at an end; for the bubbles of steam then rise copiously throughout its whole mass.

In the annexed sketch the arrangement of the flask is shown, and the convective currents indicated by ascending and descending darts.



Another beautiful experiment regarding the ascent of hot through cold water, may be made by an arrangement here shown. It represents a quart bell-glass, inverted, and suspended by wires from any convenient support: the neck of the glass is closed by a cork, through which passes a tin tube, one quarter of an inch diameter, and six inches long, soldered on to a tin bulb, one inch and a half diameter; this bulb is filled with water tinged with red ink. The bell-glass is filled with water; the upper part of which is caused to boil by the introduction of the red-hot iron ball, as at page 176.

The boiling water will now float upon the cold beneath: this being done, and the ball removed, apply the flame of a spirit lamp to the tin-bulb, so as to heat the water within it; the heated water will ascend as a red cloud through the colder water in the glass; but when it touches the boiling water on the surface, its further ascent will be arrested; therefore, at the close of the experiment, there will be two distinct strata, the upper colourless, the lower coloured.

Many are the practical applications of the facts which have been detailed regarding the heating of water, but the limits of this inquiry do not admit of their description; other curious matters demand attention.

The Air, or Atmosphere, has been represented as essentially consisting of Nitrogen and Oxygen; a minute trace of Carbonic acid is always found in it; and it also contains the Vapour of Water; in fact, air is capable of dissolving water under certain conditions.

If a cloth soaked in water be exposed to the air, the water disappears, the cloth dries; this is a common occurrence, and rarely excites a second thought; but be it remembered that the most trivial fact courts the notice of the true lover of wisdom; and many great discoveries have been made by examining the cause of things familiar. The mere drying of a cloth proves that air is capable of uniting with water, a fluid above eight hundred and fifty times heavier than air, and no more capable of rising in the air as a fluid, than the mercury in the trough has of rising through the water at page 78; but, by the action of the heat existent in air, water becomes endowed

with wings or vaporized, and ascends into, and mixes with the air, and is wafted throughout the world, for the good of all animated nature.

In the state of invisible vapour produced by natural heat, and therefore nothing like so sensibly warm as ordinary steam, water is always present in air to a greater or lesser extent. If a decanter, filled with water recently drawn from a cold spring, be placed upon the table of a warm apartment, in the course of a few minutes the brilliant glass becomes dim with dew; the water has not filtrated through the decanter, no water is visible in the surrounding air; then why does this appearance ensue?

By attending to the temperature of the water in the decanter and that of the air, an explanation can be furnished; a thermometer may show the water to be at fifty-two, and the air at sixty-five degrees, so that the watery vapour which the air contains can no longer exist as such upon coming around the cold glass; it is cooled and condensed into the state of liquid water, and bedews the glass, exactly the same as the sensibly hotter steam produced

by boiling, condensed into liquid water by holding a cold glass over it, in the experiment at page 158.

Take a more powerful source of cold, as a freezing mixture, contained in a bright tin-cup, and then not only will the vapour of the water be condensed from the air as a liquid; but the intense cold will solidify it into ice, because liquid water cannot exist at a lower temperature than thirty-three degrees, and therefore the outside of the cup will be encrusted with hoar frost.

When the atmosphere is surcharged with watery vapour, which is constantly ascending into its vast volume from the oceans and rivers of the globe, sudden changes in its temperature cause the return of the water to the earth, as rain, snow, and hail.

The annexed tables exhibit the Weight and Measure of the invariable constituents of the Atmosphere:—

	Parts by Weight.
Nitrogen	75·55
Oxygen	23·32
Carbonic acid	0·10
Watery vapour	1·03
	100·00

	Parts by Measure.
Nitrogen	77·50
Oxygen	21·00
Carbonic acid	0·08
Watery vapour . . .	1·42
	100·00

Water enters into chemical combination with many substances, and is often retained by them with very powerful affinity, so that ordinary drying will not expel it; several of those beautiful natural and artificial productions called crystals, owe their form, texture, and brilliancy to its presence; this is the case with Crystals of sulphate of lime, which are frequently of such size and transparency as to be used as a substitute for glass, but the transparency depends upon chemically combined water, though the substance does not feel damp to the touch, and if a crystal be heated in the flame of a lamp, it crumbles into an opaque white powder, as the water evaporates.

Crystallized sulphate of magnesia contains more than half its weight of water, which may be expelled by heating it in a small ladle or crucible, leaving a dry, white, shapeless, or amorphous mass; and in the experiment at

page 148, with a strong solution of sulphate of magnesia and spirit of wine, the salt was precipitated white, opaque, hard, and amorphous, because the spirit combined with, and removed the water essential to the production of crystalline form; this is technically called Water of crystallization.

The crystals of alum, at page 113, likewise owe their beauty to the presence of water, and if it be expelled by heat as above, a white crumbling mass remains, which is popularly called Burnt Alum.

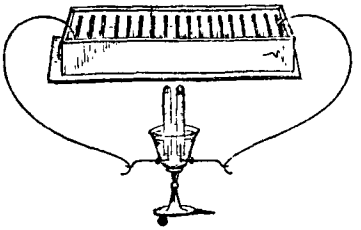
Substances containing combined water, as the foregoing natural and artificial crystals, are called Hydrous, and when deprived of it, Anhydrous; both terms are derived from the Greek, the one indicating the presence, and the other the absence of water.

In the Introductory Chapter, Water is stated to be a compound of the elements of Oxygen and Hydrogen, and therefore not absolutely simple, as the ancients imagined was the case; the methods for effecting its decomposition, and the examination of Hydrogen are next to be presented.

The operation of distillation by which water

is purified, furnishes no intelligence regarding its composition; foreign or adventitious matters alone are separated, and hence a reasonable conclusion may be drawn that the actual Elements of water are held in union by a very strong affinity, otherwise the heating or boiling would part them asunder, Fire or Heat being so opposed to attraction, not only Mechanical but Chemical; thus it melts lead, and decomposes marble, but it only changes water into steam, and this cooled, reproduces water or ice, there being no repulsion or separation induced between the elements of the water during all these proceedings.

The powerful and mysterious agency of Electricity must be summoned into activity for the decomposition of water; the simplest arrangement is that presented by the instrument called The Voltaic-trough, constructed as in the annexed figure.



It consists of a number of plates of the metals zinc and copper, about four inches square, arranged at intervals of half an inch, in a wooden box, and tightly cemented in their places, so that the cells formed by the intervals admit of being filled with water, acidulated by sulphuric acid, sufficiently to cause a slight effervescence upon the zinc plates; during this action Electricity is developed, and may be conducted, like heat, through metallic wires, from each end of the trough, to exert its power upon the water contained in the apparatus attached to the wires, as above represented; this is a small wine-glass, through which two platinum wires are inserted, and bent upwards at right angles, the glass is filled with water, as also two glass tubes, half an inch diameter, inverted over the wires.

The moment that this arrangement is completed, the Electricity generated in the trough is conducted by the wires through the Water, and causes the repulsion or separation of its Elements, Oxygen and Hydrogen, which ascend as myriads of gas bubbles and collect in the tubes; it will be observed that one of them receives only half as much gas as the other, or, in

other words, when one is only half full the other is full; the action of the trough may be now suspended, by removing the connecting wires, and emptying away the acid, and the examination of the gases undertaken.,

Let the tube, which is half full, be gently raised above the end of the platinum wire in its centre, so that a finger dipped beneath the surface of the water may close the tube, in which position it must be removed; kindle the end of a bit of wood, not larger than a Lucifer match, blow out the flame, and having turned the tube with the finger upwards, and still closed by it, quickly remove the finger and introduce the wood, yet having a glowing spark at its extremity; it will instantly rekindle, and thus prove the presence of Oxygen.

Proceed in the same way with the other tube, as regards its removal from the glass; but when the finger is withdrawn, apply the wood burning with flame, the gas will kindle with a pale flame, hardly visible in daylight; and thus prove the presence of Hydrogen.

By conducting this experiment with extreme accuracy, Chemists have determined that

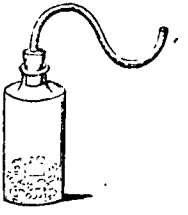
Oxygen and Hydrogen are the sole results of the decomposition of Water, and the elements invariably appear in the proportion of one part by bulk of the former, and two parts by bulk of the latter; there are refined methods of causing these gases to recombine and produce water; so that by analysis and synthesis there does not exist a doubt regarding the composition of this important liquid, which was so long deemed Elementary, but now regarded as a Compound.

Electricity is the only agent by which both elements can be simultaneously elicited from water in their free states; but there are many substances capable of eliciting the Hydrogen alone; thus, for the experiments concerning flame, the gas was obtained by the action of diluted sulphuric acid upon zinc.

The theory of the process consists in the zinc decomposing the water, and combining with its oxygen, to form an oxide, which the sulphuric acid dissolves to form a sulphate of oxide of zinc, and hydrogen is set at liberty.

Let the proportions of zinc and diluted sulphuric acid, spoken of at page 39, be placed in the bottle provided with the bent

tube, when cleansed from the result of the experiment in which carbonic acid gas was evolved at page 118, the apparatus is again shown in the annexed sketch.



Hydrogen will be evolved, and may be collected in bottles filled with water in the trough, as at page 77, taking care that the gas, which is first obtained in a pint bottle, be suffered to escape by lifting it from the trough, because it is not pure, but mixed with the common air, driven from the bottle containing the zinc and acid.

The inflammability of Hydrogen has been adverted to at page 40, but here it may be remarked that the gas will not support combustion; let a bottle full be held with the stopper downwards, and the stopper taken out in such position, then thrust a lighted taper into the

gas, it will instantly burn with flame, but the flame of the taper will cease.

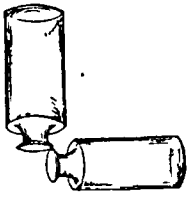
The bottle must be held in this inverted position when the stopper is withdrawn, or otherwise the Hydrogen would escape, it being permanently lighter than air, as may be proved by opening a bottle full of the gas, as it stands upon the table, leaving it a minute, and then introducing a lighted taper, it will burn quietly in the Air, which has descended into the bottle and expelled the Hydrogen.

On the other hand, if a bottle full of Hydrogen be opened in the inverted position, and so held for a few minutes, the gas will not escape, because being much lighter than air, it cannot fall through air, but will kindle at the flame of a taper.

A very beautiful experiment, in illustration of the levity of the inflammable gaseous element now under examination, may be performed by following the next instructions.

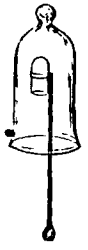
Let two similar-sized wide-mouthed bottles, one containing Air, the other Hydrogen, be held

in an inverted position, with the stopper of each removed; then, by inclining the bottle containing Hydrogen, let its mouth be placed directly under that of the other, as here shown.



The position is exactly the reverse of that used for ordinary pouring; the Hydrogen will ascend and take the place of the Air in the bottle above, whilst it descends and takes that of the hydrogen, as the application of a lighted taper to the mouth of each bottle will prove.

Another experiment yet more remarkable, is the following; let a quart bell-glass be filled with hydrogen in the trough, and then gently lifted from the surface of the water, with its mouth downwards, so as to admit of the introduction of a small tumbler, fastened to the end of a stout wire, with its mouth also downwards, as here represented.



Let the tumbler be passed upwards, until it touches the interior of the dome of the bell-glass, then steadily drawn out, and moved at some distance from the bell-glass, to the flame of a taper; the contents will kindle, and prove that Hydrogen has been drawn down, and out of the bell-glass. These last experiments with Hydrogen are directly opposed to those with Carbonic acid gas at pages 120 and 122.

In consequence of its inherent and permanent levity, Hydrogen was formerly employed for inflating balloons, but is now superseded by the gas obtained from coal, which is found sufficiently buoyant for the purpose, and can be obtained with more facility at a cheaper rate; yet the inflation of a small balloon by hydrogen is a pleasing experiment, and may be very easily performed.

Let a small balloon, about six inches diameter, be compressed gently between the hands, so as to expel the common air, and then tied with its neck over one end of a straight metal pipe, six inches long and one quarter of an inch diameter, the other end being thrust through a cork placed in the mouth of a pint

bottle, containing zinc and diluted acid: as hydrogen evolves it will be received in the balloon, and when fully inflated, upon removal, as at page 39, from the pipe, the balloon will ascend with great swiftness.

The simple apparatus for this miniature balloon ascent is here shown.

Hydrogen, when pure, burns quietly, but when mixed with Air or Oxygen, it burns with a violent explosion, therefore the greatest care must be taken in all experiments, that neither air nor oxygen become mingled with it; whenever it burns, the product of its combustion is water, as mentioned at page 41.

Knowledge of the composition of Water is a most important fact in Chemistry; it consists of

	Parts by Weight.
Oxygen	88·9
Hydrogen	11·1
	100·0

This fact enables philosophers to explain many phenomena, which were once mysterious,

and it also proves how wonderful must be the power of attraction, called Affinity, in disposing two Gases to combine and produce a Liquid; for no reasoning would ever lead to the conclusion that Water, the Ancient Element, so opposed to Fire, consisted of a Combustible, and a Supporter of combustion; or, in other words, of one of the elements of all ordinary Fire, and another of the surrounding Air, namely, Hydrogen and Oxygen; and perhaps the time is not far distant when Water will be employed as the most fertile source of Fire.

The inquiry concerning The Chemistry of The Four Ancient Elements here terminates: its object has been to excite feelings of interest regarding the enchanting Science of Chemistry, rather than to give minute information; and if the few treasures which have been displayed from this vast mine of Natural Knowledge induce those who are unacquainted with its resources, to enter upon the pursuit of more, they will find it rich and inexhaustible. They will find that, unlike its parent Art of Alchemy, Chemistry is a Science having no narrow

range nor selfish aim, but an intimate connexion with the best and highest interests of man, teaching him the just and proper value of the productions of the beautiful globe upon which he dwells, and their practical applications to his wants, his comforts, or his luxuries; and, above all, leading him to acknowledge, with reverence and gratitude, the Wisdom, Power, and Goodness of The Great God, by Whom all things were Created.

APPENDIX.

As several of the agents which are required for performing experiments in illustration of the Chemistry of The Four Ancient Elements, demand considerable caution to be exercised in their management, a few details concerning the matter will form a useful Appendix to the Essay.

Lime Water.—*Page* 22.

This valuable test for detecting Carbonic acid gas may be prepared as follows:

Take two ounces of clean chalk, (carbonate of lime,) broken into pieces about the size of hazel nuts, put them into an iron ladle, which is then to be set in a bright glowing fire, and allowed to continue red hot for an hour, at the

expiration of which nearly the whole of the carbonic acid will have escaped. Remove the ladle, allow it to cool, then shake out the substance it contains upon an earthenware plate, it is Quicklime; gently pour water upon it, and the lumps will soon crumble away with a crackling noise, and the evolution of much heat and steam. Thus the lime is slaked, and Hydrate of Lime obtained; this must be placed in a quart glass bottle filled with water; the cork or stopper being then inserted, the bottle must be shaken two or three times, and afterwards allowed to rest; the greater portion of the lime will subside, whilst the clear liquid above is Lime-water; it must be carefully poured off into another bottle, and preserved from the air by a well-ground stopper, for use. Fresh water may be added to the sediment in the quart bottle every time that clear lime-water is decanted, and thus a stock may be kept without difficulty; in the course of time, the lime will be exhausted, and this is detected by the lime-water ceasing to restore the blue colour to litmus paper which has been reddened by an acid.

Fresh lime must then be prepared, &c.

Spirits of Wine.—*Page* 24.

Chemists generally call this liquid Alcohol, a term derived from the Arabic, implying *subtlety;* it must be kept in a strong glass bottle, with an accurately-ground stopper.

Spirits of wine, or Alcohol, is highly inflammable, and should never be poured from the bottle to any vessel near or level with the flame of a lamp or candle. The vessel into which the alcohol is to be poured must invariably be set upon the table, because the volatile vapour of alcohol is heavier than air, and will not rise high enough to encounter the flame of a candle or lamp, set in a candlestick, or on a pillar of the usual height. If the bottle of alcohol and the glass or other vessel into which it is to be poured, are held level with or over the flame, whilst in the act of pouring, the heavy vapour descending may kindle, and envelope the hands in flame; they are certain to drop the bottle and glass, the contents of both will float over the table, or the clothes of the operator, as liquid flame; great danger is thus incurred, because flame

always ascends, and the face may be dreadfully burned.

Should an accident happen with Alcohol, its flame on the table may be extinguished by throwing over it a thick wet woollen cloth, and that on the person of the operator by a similar cloth quickly thrown over the part which is suffering; for, be it remembered, that the flame cannot burn without air, and the wet cloth prevents access. In a case of great danger, it is advisable to lie upon the floor, and cover the whole person with the hearth-rug, which will extinguish the flame effectually.

Spirits of wine or Alcohol is a very excellent fuel for lamps which are required for heating glasses, &c. as at page 68, because it deposits no soot, the products of its combustion being only carbonic acid and water. A spirit-lamp should have a cap or cover to put over the wick to prevent the Alcohol from evaporating when the flame is extinguished.

Ether.—*Page* 31.

This liquid must be kept in a strong glass bottle, with an accurately-ground stopper, tied

over with glove-leather, because it is more volatile than Alcohol, and the expansion of its vapour in a warm room frequently forces out the stopper, if not thus secured.

Ether is highly inflammable, and the same precautions as those given regarding alcohol must be observed in pouring it from the bottle to another vessel; its vapour is heavier than that of Alcohol, and its flame far more difficult of extinction by the means described, but none other can be employed.

To avoid the chance of an accident, it is best to decline making experiments with Ether by candlelight; but even in daylight the flame of the paper employed to kindle the Ether, as at pages 31 and 32, should be carefully held above and away from the tin-cup into which the ether is poured, until the moment that it is required to be inflamed. Strict care must always be taken to insert the stopper of the bottle of Ether, to tie it over with the leather, and then remove the bottle away from the table upon which the tin-cup or other vessel stands containing the requisite portion of ether to be kindled.

PHOSPHORUS.—*Page* 32.

This element is usually sold in small rods, about the size and length of cedar drawing-pencils; it is soft like wax, very inflammable, and must be kept in a vial full of water. Phosphorus, when required for an experiment, must be shaken from the vial into a basin of water; then removed by means of a pair of scissors, or pliers, and placed upon a flat board; the proper portion of phosphorus can then be cut off with a pen-knife, and the remainder replaced in the vial, filled with water as before. The small portion of phosphorus, recently cut off, must be removed on the point of a knife to a few folds of white blotting paper, and gently pressed between the folds to absorb the adhering water. This being done, remove the phosphorus by means of the knife, and place it in the small ladle.

Dry phosphorus must neither be held between the fingers nor strongly rubbed, because it will inflame by warmth or friction, and produce most painful burns, which are extremely difficult to heal.

By following these directions, Phosphorus may be safely experimented upon; but should it accidentally take fire and burn the hands, let them be plunged instantly under water, which will extinguish the flame, and whilst there the phosphorus must be perfectly removed from the injured part, which afterwards will require the same treatment as an ordinary burn.

Sulphuric Acid.—*Page* 39.

This powerful acid is a transparent, colourless, heavy liquid, and though not volatile at common temperatures, it must be kept in a strong glass bottle, having an accurately-ground stopper, for it attracts water from the air, and becomes weakened.

Sulphuric acid is dangerously corrosive, producing most painful and troublesome wounds if it fall upon the person; it must be poured with the greatest caution from the bottle into other vessels, without gurgling, and during the operation it must not be held level with the face, lest it accidentally splash, and do injury: it is not inflammable. If injury be received

from sulphuric acid, water must be plentifully applied with a large towel to the part, to wash away the acid; a little water will only increase the burning sensation. If the acid be spilled upon the table, a thick flannel, well soaked in water, will remove the greater part, but some will remain, and its effect may be neutralized by washing the table over with whiting and water, or carbonate of soda and water, until effervescence ceases. The towel and flannel must be soaked in water containing carbonate of soda, to neutralize the acid which they have absorbed, for if suffered to remain it would corrode and destroy them.

If sulphuric acid fall upon the clothes, water must be applied, and then carbonate of soda, smelling salt, hartshorn, or sal volatile, to neutralize its effects.

When experimenting with sulphuric acid, the bottle containing it must always be set in an earthenware plate, so that any drops adhering to the lip of the bottle may trickle down into the plate, and do no injury to the table.

Sulphuric acid must never be added suddenly to water, for intense heat will be evolved,

which will break glass vessels, and then much damage will ensue.

HYDROGEN.—*Page* 40.

In evolving Hydrogen by the action of diluted sulphuric acid upon Zinc, the effervescence must be allowed to continue for several minutes before the application of flame to the end of the brass pipe; the object of this delay is to ensure the expulsion of common air from the bottle; if this precaution be neglected, if the flame be applied immediately after the insertion of the cork and brass pipe, an explosion will inevitably happen, which may be attended with danger, either from the bursting of the bottle or the thrusting out of the pipe. It is a good plan to fold a thick cloth several times round the bottle, then to place it in a box, so that the pipe may just project beyond the top; a lighted slip of paper may be applied to it at arm's length, and even if an explosion should happen, no damage can ensue. If the effervescence do not ensue very rapidly, more time must be allowed to elapse

before the light is applied to the pipe; but the proportions of materials, stated at page 39, will generally evolve Hydrogen very rapidly, and three minutes will be sufficient; when the effervescence has nearly subsided; the small flame of hydrogen at the end of the pipe must be blown out, before removing the cork to throw away the residue of the operation.

Red Precipitate.—*Page* 75.

The Chemical name for this compound is Binoxide of Mercury, denoting that it contains two (Latin, *binus*) proportions of oxygen, and one of mercury; for there is another oxide of the metal, containing only one proportion of oxygen and one of mercury, generally called the oxide.

For example, 8 parts by weight of oxygen, combine with 200 parts of mercury, to produce 208 of Oxide of mercury; but twice 8, or 16, parts by weight of oxygen combine with 200 parts of mercury to produce 216 of Binoxide of mercury.

This Binoxide of mercury must be purchased

in the form of dark red crystals, and not in powder; a preparation called Nitrico-oxide of mercury is often sold in its stead; but this is perfectly unfit for the evolution of pure oxygen. Binoxide of mercury is poisonous; it is best preserved in a stoppered bottle.

Litmus Paper.—*Page* 86.

This useful test of the presence of common acids is made by pouring warm water into a cup containing half an ounce of a blue vegetable matter called Litmus, (which may be purchased at a druggist's); the infusion thus obtained has a dark blue colour; this may be diluted or rendered paler by the addition of more water, until nearly sky-blue; it must then be poured off clear into a shallow plate; pieces of white blotting-paper, the size of this page, are then to be drawn through the infusion; and, thus stained, are afterwards hung on lines to dry. Blue litmus-paper must be kept in a stoppered bottle, out of the access of light and air, or its colour will fade; it reddens immediately upon being dipped into an

acid gas, or acid solution, and its colour is restored by alkalies and alkaline earths.

Muriatic Acid.—*Page* 117.

Chemists call this substance Aqueo Hydrochloric acid, because it consists of Hydrogen and Chlorine united and dissolved in Water; but it is popularly known as Muriatic acid. It is a very pale straw-coloured liquid, not so heavy as Sulphuric acid, and must be kept in a strong glass bottle, having an accurately ground stopper, tied over with a piece of sheet lead, because the acid is volatile, and in a warm room the vapour would force out the stopper, if not thus secured, and it would corrode leather. Muriatic acid emits white fumes when poured from the bottle; the inhalation of these must be avoided, as they are very irritating; the acid must be poured without guggling or splashing; and the bottle containing it set on a plate, as directed for sulphuric acid; accidental splashes with muriatic acid must likewise be treated with water, whiting, carbonate of soda, or sal volatile; Muriatic acid is not inflammable.

CHARCOAL.—*Page* 129.

Charcoal obtained from the bark of a tree burns more brilliantly in oxygen than common charcoal, which is generally obtained after the branches are barked.

A small quantity of bark charcoal can be readily procured, by placing a piece of oak, elm, or willow bark, in an iron ladle, filling it with sand, and then heating the ladle red-hot in a bright fire, until flame ceases to rise from the sand. Withdraw the ladle from the fire; let its contents cool; then shake out the sand, and the charcoal will be found fit for the experiment.

GREEN AND RED FIRE COMPOSITIONS.—*Pages* 152 *and* 154.

The nitrates of Baryta and Strontian are both crystalline Anhydrous salts; but if they happen to be damp from adventitious water, they must be dried, by spreading them on an earthenware plate, placed before the fire.

Chlorate of Potassa is a crystalline Anhydrous salt; but if damp, it must treated as above.

There is no danger in drying these salts, or in reducing them separately to powder, but the greatest care must be taken that neither sulphur, charcoal, sulphuret of antimony nor phosphorus, accidentally mingle with Chlorate of potassa during the operation of powdering, because a violent and dangerous explosion would happen; the contact of sulphuric and muriatic acids with Chlorate of Potassa must likewise be avoided.

The Voltaic Trough.—*Page* 188.

An Apparatus thus named in honour of Professor Volta.

A voltaic trough, containing twenty plates of four inches square, when charged with diluted sulphuric acid, is a very powerful instrument. The mode of proceeding is as follows: pour water into the cells of the trough until they are all filled within one quarter of an inch of their tops, then empty the water into an

earthenware basin, and gradually add sulphuric acid, (stirring the while with a stick,) until feeble effervescence is produced upon a bit of zinc thrown into the diluted acid.

By dipping a small earthenware jug into the diluted acid, it may then be poured into the cells of the trough until they are all filled as above.

Two pieces of thin copper bell-wire, about eighteen inches long, must have their ends brightened with emery paper; these are called conducting wires, and one is to be placed in the cell of the trough, on the right, and the other in that on the left hand of the operator, as shown in the cut at page 188.

The wetted fingers, simultaneously touching these conducting wires, will receive a slight shock, and this announces that Electricity is generated; the connexion may then be made with the platinum wires of the decomposing apparatus, merely by hooking them on.

When the experiment is concluded, and the acid emptied away, the trough should be well washed with water and allowed to drain; and if thus treated after each time of using, it will remain a serviceable apparatus for many other experiments.

All the liquid agents above mentioned must be carefully placed in a box lined with sheet-lead, that in case of leakage, no damage may be done to the furniture of an apartment; the box must never be left accessible to any person, in the absence of its owner.

The results of all experiments, when useless, must be carefully thrown away, and the vessels which contained them well cleansed with water.

The face of the Chemical operator must never be held immediately over any vessels in which experiments are proceeding.

By attending to the foregoing instructions, the experiments may be performed with safety and success.

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LONDON:

PRINTED BY G. J. PALMER, SAVOY STREET, STRAND.

Digitized with financial assistance from the
Government of Maharashtra
on 23 January, 2019